G.E.C. Journal

VOL. XVII. JANUARY, 1950 No. 1

CONTENTS

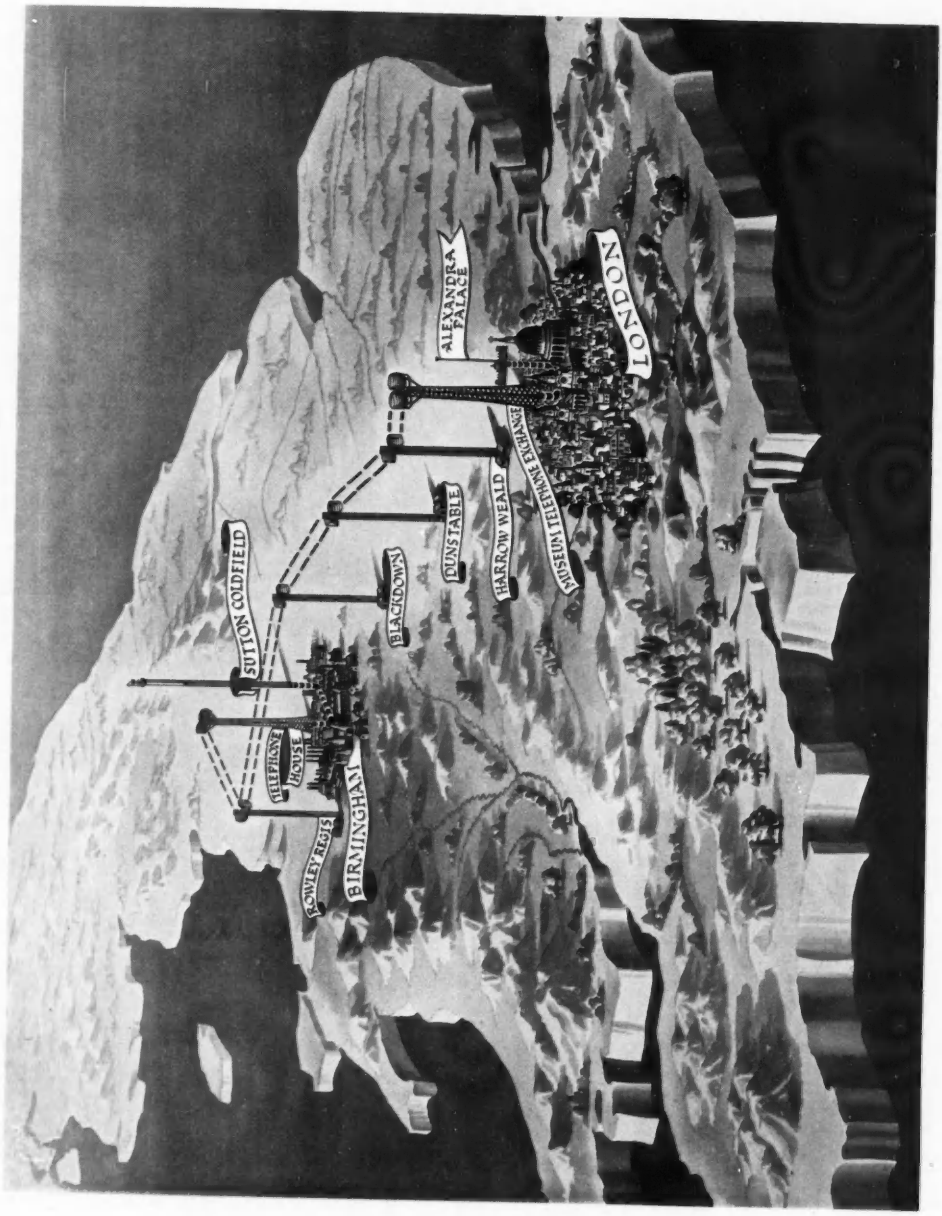
	PAGE
FRONTISPIECE : ROUTE OF LONDON-BIRMINGHAM TELEVISION RADIO-RELAY LINK	2
THE LONDON-BIRMINGHAM TELEVISION RADIO-RELAY LINK - - - - *By D. C. Espley and R. J. Clayton*	3
ELECTRICAL PROGRESS AND DEVELOPMENT - - - - - - - - - *Contributed by members of the Technical Staffs of the Works and Research Laboratories of the Company :*	
POWER EQUIPMENT - - - - - - - - - - - -	11
MINING GEAR - - - - - - - - - - - - -	21
ROLLING MILLS - - - - - - - - - - - - -	23
INDUSTRIAL ELECTRIFICATION - - - - - - - - - -	24
TRANSPORTATION - - - - - - - - - - - -	26
MARINE ELECTRICAL EQUIPMENT - - - - - - - - - -	30
ELECTRIC MOTOR DEVELOPMENTS - - - - - - - - -	31
MECHANICAL HANDLING - - - - - - - - - - -	33
TELECOMMUNICATIONS - - - - - - - - - - -	35
X-RAY EQUIPMENT - - - - - - - - - - - -	40
MEASURING INSTRUMENTS - - - - - - - - - - -	42
LAMPS AND ILLUMINATION - - - - - - - - - - -	44
INDUSTRIAL AND PROCESS HEATING - - - - - - - - -	51
AGRICULTURAL EQUIPMENT - - - - - - - - - - -	53
DOMESTIC APPLIANCES - - - - - - - - - - -	54
TECHNICAL LITERATURE - - - - - - - - - - - -	56

Published by

THE GENERAL ELECTRIC COMPANY, LIMITED

Magnet House, Kingsway, London, England.

COPYRIGHT.



ROUTE OF LONDON-BIRMINGHAM TELEVISION RADIO-RELAY LINK.

The London-Birmingham Television Radio-Relay Link

By D. C. ESPLEY, D.Eng., M.I.E.E., and R. J. CLAYTON, M.A., A.Inst.P.
G.E.C. Research Laboratories.

Increasing attention has been paid in the post-war period to the development of radio links as integral parts of telecommunications networks. The characteristics of the signals to be transmitted, the topographical features of the terrain to be spanned, or the mobile nature of the units concerned, may require radio links rather than telephone lines and cables. Developments have been made in both U.H.F. and V.H.F. wave bands. Both of these are suitable for various forms of multi-channel telephony, but the former has the practical advantage that simultaneous transmission of telephony and television signals can be arranged.

One of the outstanding features of electrical progress during 1949 was the erection of the London-Birmingham Television Radio-Relay Link. In its final form it will provide for simultaneous two-way transmission of television signals between the two cities, but at present a single channel reversible link has been installed. The general description given in this article will be followed by a detailed technical account after the two-way link has been completed.

INTRODUCTION.

THE London - Birmingham Television Radio Relay-Link, which on December 17th started in regular operation for the relaying of B.B.C. television programmes from London to the Midlands, marks the first stage in an extensive programme of development of the television service in the British Isles. Unique features make this Link outstanding amongst such systems throughout the world. No other Link provides such comprehensive arrangements for the remote control of repeater equipment throughout the system and for the remote switching of standby equipment. Every detail of the system has been arranged to give the utmost reliability in operation and elaborate precautions have been taken for rapid action, often automatic, should a fault occur. The quality of the signal derived from the link is such that the picture available to viewers in the Midlands service area, and also within the range of subsequent provincial stations, should be indistinguishable from that available to viewers in the London area.

The system now being put into regular operation has been designed, manufactured and installed by The General Electric Company, Limited, to a specification set by the General Post Office. It provides for the transmission of 405 line, 50 frames/second, television signals of the waveform transmitted at present by the B.B.C. from Alexandra Palace and also, in the future, from Sutton Coldfield, Birmingham. The contract issued by the G.P.O. in May, 1947, called for the interconnection of London and Birmingham, but also required the design of a system capable of extension to 400 miles or more. The London Terminal of the system is at Museum Exchange, Howland Street, and the Birmingham Terminal at Telephone House, Newhall Street.

GENERAL DESCRIPTION.

The Television Link provides for simultaneous two-way transmission of television signals between the two cities, but the installation programme allowed for the work to be completed in two stages. The first part of this programme is now complete and a single channel reversible link has been installed so that transmission in either direction can be obtained as desired. This is the first time that a link of such length has been erected incorporating automatic switching from its ends capable of reversing the radio chain through unattended intermediate stations in accordance with programme requirements at the two terminal stations.

When the second part of the installation has been completed in the middle of the year a

complete duplex system will allow simultaneous transmission in both directions of independent television programmes.

An artist's impression of the route of the London to Birmingham Link is shown in the frontispiece. The present reversible system makes use of transmission frequencies of approximately 900 Mc/s, corresponding to wavelengths of nearly 33 cms. The use of these frequencies necessitates uninterrupted optical paths between transmitters and receivers for satisfactory and consistent performance. It has been necessary to provide four repeater stations between London and Birmingham and full use has been made of natural topographical features —the " Elstree " ridge just north of London, the Chiltern Hills, the Cotswolds and high land to the west of Birmingham. The system was originally designed for maximum repeater station spacings of forty miles and, in fact, the present system includes two sections of this length. The station to the West of Birmingham was chosen to be suitable for extension of the system northwards.

Each repeater station receives the radio signal from the previous station, amplifies it and transmits it to the next one. The sites for the four repeater stations were chosen after an extensive series of field trials of radio wave propagation conditions between the sites. The final choice had to take into account not only the technical results of these trials, but also such matters as the preservation of amenities and the problems arising from proximity to airfields.

For the two-way link the radio equipment at each repeater station will be installed in a special cabin at the top of a lattice tower which carries four paraboloidal aerials. Fig. 1 shows a model

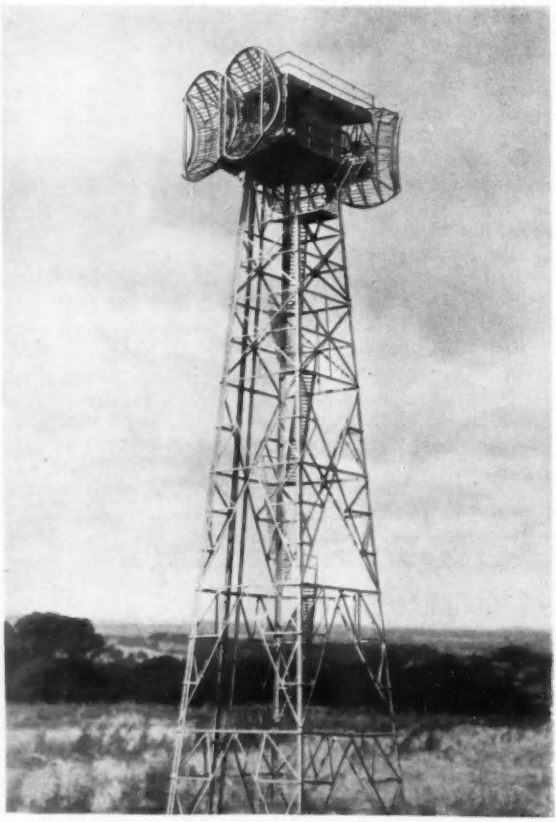


Fig. 1.—Model of final repeater station tower.

Fig. 2.—Paraboloidal aerials on temporary mast.

of one of these towers in natural surroundings. The present reversible service has been provided without the erection of these special towers and cabins. At each station two aerials are erected on a temporary mast and the radio and other equipment is installed in buildings at its foot. These buildings will eventually house only the standby generating equipment and power units. Fig. 2 shows a pair of these paraboloidal aerials on one of the temporary masts and fig. 3 shows a typical complete temporary installation at Blackdown. Figs. 4 and 5 are photographs of the terminal stations in London and Birmingham respectively.

PRINCIPLES OF OPERATION OF THE LINK.

The radio signal is transmitted over the Television Link by frequency-modulation of the carrier. The present installation uses two transmission frequencies : 870 and 890 Mc/s. A station which receives on 870 Mc/s re-transmits on 890 Mc/s and vice versa. These two frequencies are used for either direction of transmission at present, but eventually, in the full two-way system, they will be employed for one direction only (London-Birmingham). For the reverse direction frequencies of 917 and 937 Mc/s will then be used in addition. The power transmitted from each station is of the order of 10 watts and this corresponds to a received power of just over 1 microwatt for free space propagation over a 40 mile path. The gain required in a repeater station may, therefore, amount to as much as 70 decibels, which involves a power amplification of 10,000,000 to 1.

At the Terminal station the frequency modulation of the carrier is achieved in two steps. The vision-frequency signal, corresponding to the television picture to be relayed, is taken from G.P.O. equipment through a coaxial cable. It is then used to frequency-modulate a 34 Mc/s oscillator over the range 32·5 to 35·5 Mc/s. This modulated oscillation is amplified and applied to the final stage of the transmitter together with the output of the carrier frequency generating chain. For convenience this will be referred to subsequently as the 900 Mc/s carrier, although, in fact, the actual frequency corresponds to one of the four frequencies detailed in the previous paragraph. In this final stage of the transmitter, frequencies are therefore generated which differ from that of the 900 Mc/s carrier by amounts equal to the frequency of the modulated oscillation.

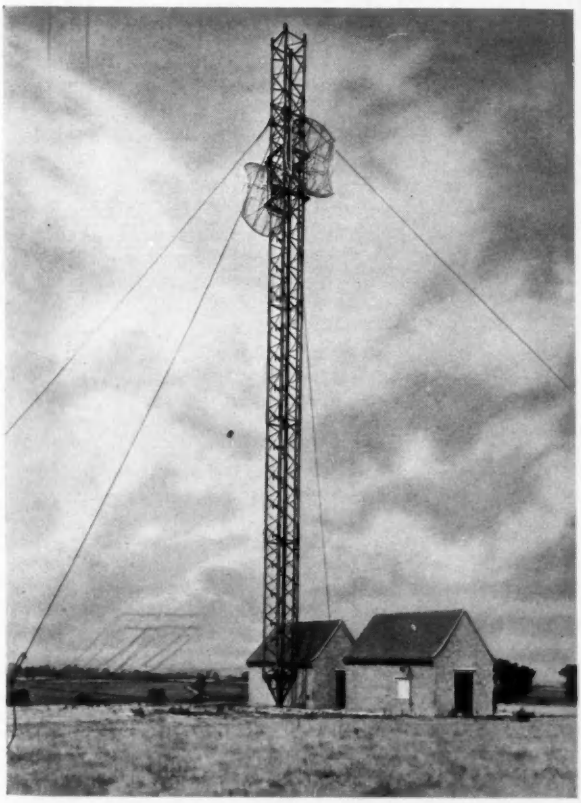


Fig. 3.—Repeater station at Blackdown.

Two modulated carrier signals have now been produced, the frequency of one of which is above, and the other below, that of the original carrier. Each signal is frequency-modulated by the vision-frequency picture signal to the same extent as was the 34 Mc/s oscillator. One of these frequency-modulated carriers is selected by filters and constitutes the signal radiated to the next repeater station.

The receiver at this next station accepts the signal which is then heterodyned by a local oscillator to give a difference frequency of 34 Mc/s. This intermediate frequency signal (which corresponds to the one produced at the first stage of the terminal transmitter) is then amplified and fed into the final stage of the transmitter

at the repeater station. The same process which was employed in the terminal station transmitter now produces a new signal for radiation to the next repeater station. This transmitted signal is passed on through the four repeater stations until it reaches the terminal receiver where it is finally demodulated to the original vision-frequency. The use of this system avoids difficulties of amplifier design and operation at low vision frequencies.

The transmitting frequency at a repeater station cannot be the same as the receiving frequency at that station since the receiver would then receive power from the local transmitter as well as

Fig. 4 (*left*).—London terminal tower on the Museum telephone exchange.

Fig. 5 (*above*).—Birmingham terminal tower on Telephone House, Newhall Street.

from the previous station. For this reason, therefore, the frequency of the receiver local oscillator cannot be the same as that of the master-oscillator in the transmitter. The local oscillator frequency is, in fact, derived from part of the transmitter master-oscillator output by the following process. The transmitter master-oscillator is heterodyned with that of a crystal-controlled oscillator whose frequency is equal to the difference between the received and transmitted frequencies (20 Mc/s). By arranging for the local and the master-oscillator frequencies to be each above, or each below, the received and transmitted frequencies respectively, the transmitted frequency is made independent of the drift of the station master-oscillator. It is, in fact, affected only by the very small drift of the crystal-controlled oscillator. Since only two frequencies are used for the signals propagated between stations corresponding to one channel of the link, the shift of frequency is the same at all repeater stations. It is alternately added to, or

subtracted from, the station master-oscillation frequency.

The aerials used throughout the link consist of paraboloidal reflectors built up from light-alloy tubes, a dipole fed from a coaxial-line, and an adjacent parasitic reflector. The full diameter of the paraboloid is 14 ft., but its horizontal aperture has been cut to 10 ft. with very little loss of efficiency since horizontal polarisation of the radiated signal is employed. The tolerance on the shapes of the reflecting surfaces does not exceed $\pm$ 1 cm. The gain of the aerial is 27·5 decibels with reference to that of a half-wave dipole. Coaxial cables are used throughout as feeders for the 900 Mc/s energy.

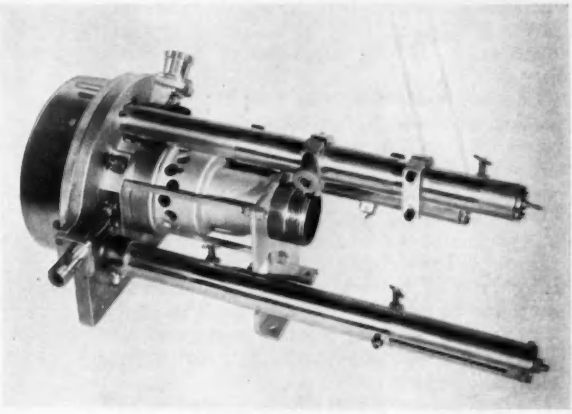


Fig. 7.—Coaxial line circuit.

STANDBY, CONTROL AND SUPERVISORY MONITORING EQUIPMENT.

It has been noted that the repeater stations are unattended. In spite of this the entire Link is under complete control from its Terminal stations and is extremely reliable in operation. These unique features have been achieved in the following manner. Duplicate signal channel equipment and power units, with changeover switching, are provided to maintain the operation of the Link if a failure should occur in any of the working equipment. The units which are not in use are kept warmed up in the " standby " condition, ready for immediate operation. The aerial systems and transmitter output filters are not duplicated, since the chance of failure in these is very remote. A novel type of contactless radio frequency changeover switch has therefore been designed and is installed in the feeder between the transmitters and the output filter to make the changeover if one of the transmitters should fail. This special switch is illustrated in fig. 6.

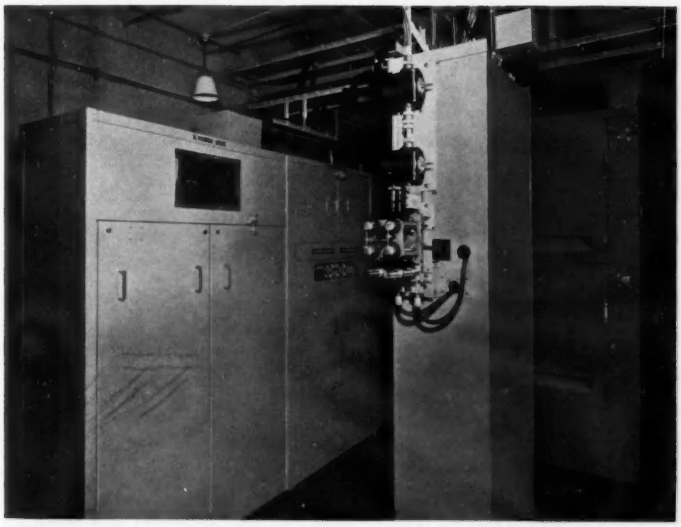


Fig. 6.—Interior view of the equipment building at Blackdown showing contactless R.F. switch mounted on the side of the receiver with resonant cavity filter above.

The power units are arranged with switching equipment which allows both signal channel units to be connected to either power unit.

In the repeater stations the radio frequency input from the receiving aerial is fed through the receiver input filter and through a second special radio frequency switch to the selected receiver. The transmitter feeder changeover arrangement is the same as at a terminal transmitting station. Duplicate equipment is provided as at a terminal station, but the receiver and the transmitter are treated as a single unit in the switching arrangements. At a terminal receiving station the same receiver feeder

arrangements are provided as at a repeater station.

The mains supply at each repeater station is supplemented by auxiliary generator equipment (provided by the G.P.O.) which comes into operation automatically if the supply mains fail. At the terminal stations the customary arrangements are made for maintenance of the electric supply.

Complete control of each channel throughout the link is maintained from a control point in the Post Office building which houses the receiving terminal for that channel. Each unit of equipment throughout the system is provided with fault-monitoring apparatus, and fault indications are transmitted automatically to the appropriate control point over a four-wire Post Office line, using a voice frequency signalling system. The same line conveys the control signals from the control point to the repeater stations and also provides the speech circuits for the control telephone between stations.

At both control points the monitoring indications received from each repeater station include information on :

(*a*) whether the station is working,
(*b*) which channel equipment and power unit have been selected,
(*c*) the occurrence of faults,
(*d*) the subsequent operation of the automatic changeover equipment,
(*e*) the maintenance of mains supply and (in the case of the repeater stations)
(*f*) whether the standby generator is working.

If a fault occurs on the supervisory system this, too, is indicated at the control point.

At both control points the operator can switch the equipment at all the stations on and off, and can make the changeover between working and standby units. These operations may be performed for all the stations at once or for each station individually. The entire supervisory system may also be checked. If this supervisory system itself fails, then the stations will continue to operate automatically on a preset time switching schedule.

At every station equipment is provided for an operator to carry out all the normal control and monitoring operations for that station. All the radio stations and control points are linked by a control telephone which has selective ringing, but a common speech channel for all the stations.

Comprehensive test equipment is provided for the assessment of the overall vision-frequency response of the entire system. In addition, each control point, receiver terminal and repeater station is equipped with a monitor for checking the waveform of the signals and the quality of the transmitted picture. Each station is also provided with special radio frequency test equipment.

VALVE AND CIRCUIT DESIGN.

The link system makes extensive use of new and advanced techniques in valve and circuit design, many of which are derived from the Company's wide experience in radar development during the second world war. The radio-frequency equipment is largely designed around the Osram disc-seal triodes DET 24 and ACT 25 used in special coaxial-line circuits, of which fig. 7 illustrates a typical example.

These circuits have interesting features and are markedly different from the combinations of coil inductances, condensers and resistances used at lower frequencies. Their characteristics are derived from resonant coaxial cavities whose construction depends upon precision mechanical engineering, requiring the use of machine tools rather than coil winding machines. Reliable and stable operation over long periods is obtained by robust construction and the elimination of sliding contacts.

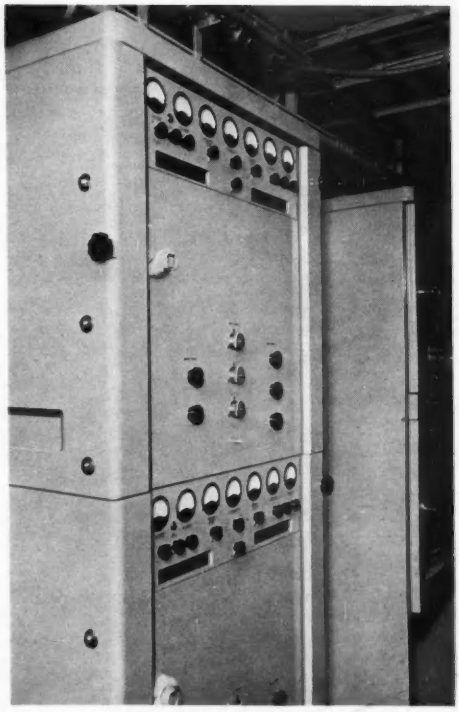


Fig. 8.—Exterior of transmitter cabinets showing alternative transmitters.

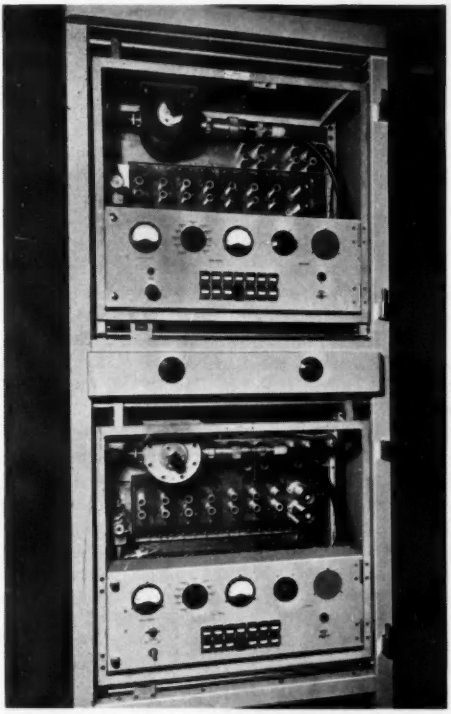


Fig. 9.—Interior view of receivers.

The transmitter unit illustrated in fig. 8 comprises the following stages.

(*i*) Master-oscillator (Osram DET 24 valve).
(*ii*) First R.F. amplifier (DET 24 valve).
(*iii*) Second R.F. amplifier (ACT 25 valve).
(*iv*) Modulator or frequency changer (ACT 25 valve).

In addition there is a frequency-shifter stage (DET 24) for the derivation of local oscillator power and an associated 20 Mc/s crystal-controlled shift-frequency generator.

In normal operation the transmitter gives full output with a drive of 4 volts peak-to-peak of intermediate frequency signal. This signal is amplified to the required level in a wide-band amplifier using Osram A1820 and KT67 valves.

The receiver unit is illustrated in fig. 9. It comprises the following stages :

(*i*) A silicon crystal frequency-changer, deriving local oscillator power from the transmitter through a filter consisting of two cavity resonators. These remove unwanted components generated in the frequency-shifter unit.
(*ii*) Two intermediate frequency amplifiers, each using a pair of Osram E1714 low-noise triodes.
(*iii*) Three A.C. automatic gain-controlled stages, each using a pair of Z77 pentodes.
(*iv*) Two further stages each using Z77 pentodes.
(*v*) A cathode-follower stage consisting of a pair of A1820 valves.

Two main types of radio-frequency filters are used. The first type employs pairs of coupled resonant cavities forming a band-pass filter. The second type is a special band-elimination filter based on the properties of multiple resonant lengths of transmission lines. Examples of these types of filters can be seen in figs. 6 and 10 respectively. Similar principles in the use of resonant lines are employed in the special contactless radio frequency switch used to change over the transmitters and receivers (fig. 6).

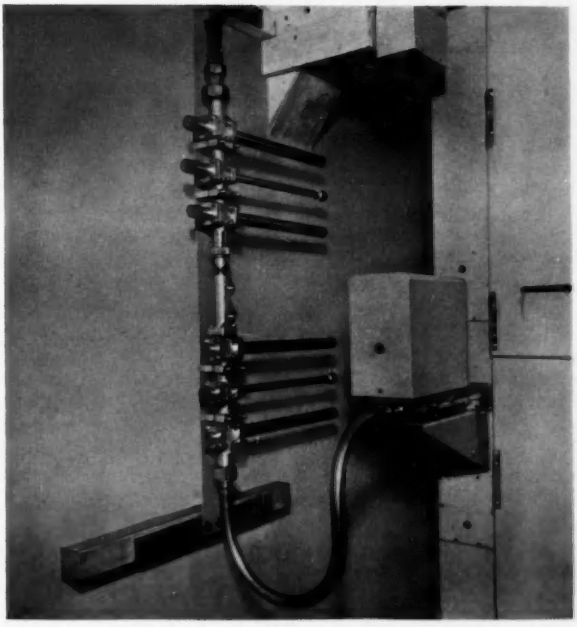


Fig. 10.—Resonant-line type filters at Birmingham terminal.

The details given above relate to the complete duplex system. For the reversible single link now in operation, where only two aerials are provided at each repeater station, the transmitter and receiver are each connected to both aerials. This implies a physical path from transmitter to receiver and the changeover operation is carried out with the use of additional contactless switches. The receiver is protected from signals from the transmitter by a combination of line and cavity filters.

It is worth noting that the reversible single channel link has been provided with just over 60 per cent of the complete radio equipment which will be used in the final duplex channel scheme.

CONCLUSION.

In this present account of the Television Link it has been possible to give only a general description of its design and operation. More detailed material will be available for publication later when the full system is installed and in operation. It is perhaps worth recording, at the conclusion of this preliminary account, some of the outstanding events in the development programme.

The specification was issued by the General Post Office in November, 1946 and extensive field trials were then carried out by a small research team from the Research Laboratories of the Company during December, 1946 and January, 1947. These trials, which were made at the depth of the most severe winter for many years, proved that the system was practicable. An instruction to proceed with the project was received by the G.E.C. in May, 1947. The building up of the necessary team at the Wembley Research Laboratories began immediately and the design of the present system was begun.

Just over a year later, in June, 1948, a successful demonstration was given of transmission of 405 line television signals using apparatus typical of the developments made up to that date. This demonstration followed upon the conclusion of extensive field-testing of the route which had been finally chosen. The following year was devoted to further engineering of the equipment and the elimination of incidental technical difficulties.

The production and installation of the equipment has been carried out jointly by the G.E.C. Telephone Works, Coventry, and the Research Laboratories, Wembley. It culminated on August 31st, 1949, in the first transmission of television signals, from a temporary terminal station at the Wembley Research Laboratories through Harrow Weald, Dunstable, Blackdown and Turner's Hill repeater stations, to the Telephone House Terminal Station, Birmingham. This transmission included pictures broadcast by the British Broadcasting Corporation from Alexandra Palace and received at Wembley for relaying through the Link.

Electrical Progress and Development

Contributed by Members of the Technical Staffs of the Works and Research Laboratories of the Company.

INTRODUCTION.

DESPITE the difficulties which British industry faced during the past year, figures of post-war as against pre-war production compare favourably with those of any other country engaged in the war.

The target set for the export of electrical goods for the year 1949 was 291 per cent above 1938. It is encouraging, therefore, to record that total shipments by the G.E.C. in 1948/9 represented an advance of 313 per cent over 1938.

The Company's confidence in the future is well demonstrated by major extensions at Witton Works and at Fraser & Chalmers Works, Erith, for the production of capital plant both for home and export needs.

Export contracts include five new 30,000 kW turbo-alternator sets for the Orlando Power Station, Johannesburg, whose eventual aggregate output will be 337,500 kW.

Hydro-electric equipment is being built for Tasmania and Tanganyika and much other power plant for Australia, India, Uganda, Malaya, Spain, Palestine and Egypt.

The opening of the London-Birmingham television link marked an epoch in television transmission technique and has enhanced the prestige of British radio the world over.

POWER EQUIPMENT.

Turbo-Generators and Compressors.

The past year has been notable for the many new orders received from overseas. Of these, the most outstanding is that from the Electricity Department of the City of Johannesburg for additional generating plant for the Orlando Power Station which will almost double its capacity. There are already three 37,500 kW sets in service (fig. 1) and two similar units are now being built. As main contractors, the Company is to supply a further five sets, each rated at 30,000 kW, which will bring the ultimate capacity of this station up to 337,500 kW. These sets are, as in the case of the original units, designed for a steam pressure of 600 lbs. per sq. in. (gauge) and a total temperature of 800 degs. F.

A number of pass-out sets are on order, brief particulars of which are as follows :

A 6,000 kW unit for the Sheepbridge Coal and Iron Co. Ltd., the turbine of which is designed for a steam pressure of 600 lbs. per sq. in (gauge) and a total temperature of 800 degs. F., and will be capable of passing out a maximum of 56,000 lbs. of steam per hour at 160 lbs. per sq. in. The turbine, which runs at 3,000 r.p.m., is direct coupled to an alternator designed for 6,600 volts.

The set for Caldwells Paper Mill Co. Ltd., is a 5,000 kW unit operating with steam at 250 lbs. per sq. in., 650 degs. F. total temperature and passing out 100,000 lbs. of steam per hour at 20 lbs. per sq. in.

Inveresk Paper Co. Ltd. have on order a 4,000 kW unit designed for a steam pressure of 315 lbs. per sq. in., a total temperature of 730 degs. F., and for passing out 75,000 lbs. of steam per hour at 30 lbs. per sq. in.

An additional order for a high pressure 7,500 kW turbo-alternator set comes from the Skinningrove Iron Co. Ltd., for whom a turbo-blower is at present in course of construction. In this case the steam pressure is 235 lbs. per sq. in. and the total temperature is 675 degs. F.

In connection with the hydro-electric scheme in Tasmania, four 25,000 kW, 600 r.p.m. vertical shaft alternators are being built for Tungatinah Power Station. These machines will be driven by Boving water turbines and will generate at 11 kV. Other overseas contracts for generating plant include a 6,250 kVA hydro-electric set for Tanganyika and a 2,500 kVA geared high pressure turbo-alternator set for the Government of Orissa in connection with the Cuttack Thermal Scheme. The turbine is designed for 250 lbs. per sq. in. steam pressure and 650 degs. F. total temperature ; it runs at 6,000 r.p.m., and the speed of the alternator is 1,500 r.p.m.

Eight turbo-type compressors each having a capacity of 20,000 cu. ft. of air per minute at 100 lbs. per sq. in. have been ordered for gold mines in South Africa. They are designed to run at 5,000 r.p.m. and are driven through speed increasing gears by 4,485 h.p., 1,500 r.p.m. self-starting synchronous motors.

For the Johannesburg Consolidated Investment Corporation there is a contract covering three turbo-compressors each having an output of 25,000 cu. ft. of free air per minute against a pressure of 100 lbs. per sq. in. A 5,330 b.h.p. motor drives the compressors through speed increasing gears, the gear ratio being 1,500/4,600 r.p.m.

Two motor-driven turbo-compressors are on order for Strathmore Investments Ltd., which will be similar to those being supplied to the anodes for supplying the motor fields. The grid voltage is varied by a Reavell-Askania constant volume regulator so that the output voltage of the rectifier, and consequently the speed of the motor, are varied automatically so as to maintain the volume of air at the desired figure. The contract also includes a 3,900 kVA power transformer and duplicate busbar metalclad switchgear with spring-operated oil circuit breakers.

There are, in all, 30 motor-driven compressors

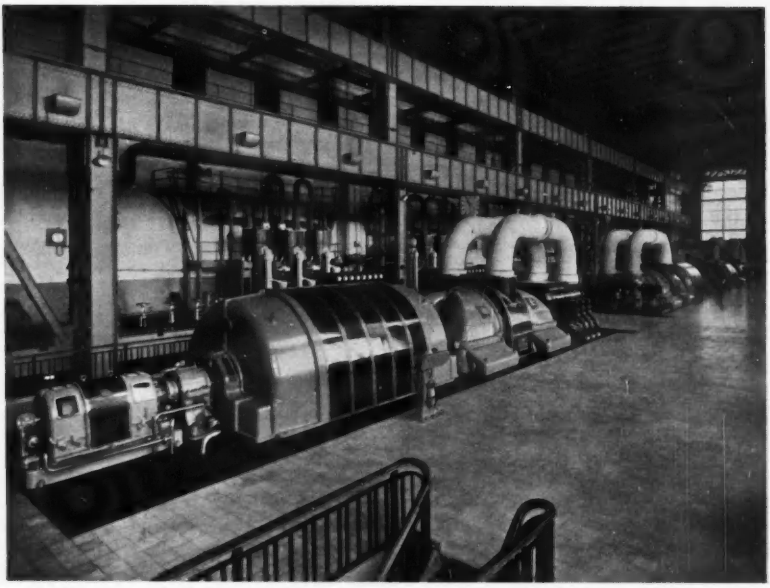


Fig. 1.—The Orlando Power Station of the Municipality of Johannesburg showing three 47,000 kVA, 11kV turbo-alternator sets.

New Consolidated Goldfields of South Africa. They will have a capacity of 15,000 cu. ft. of air per minute, the motor being rated at 3,400 h.p.

Fig. 3 shows a typical motor-driven turbo-compressor supplied to the Rand Mines Ltd. It deals with 20,000 cu. ft. of air per minute, the outlet pressure being 92·1 lbs. per sq. in. absolute, and is driven by a 3,935 b.h.p. motor through a set of speed increasing gears having a ratio of 1,500/5,000 r.p.m.

Particular interest attaches to the order for two motor-driven turbo-type blowers for blast furnaces at the Park Gate Iron & Steel Company Ltd., Rotherham. Each blower has an output of 30,000/25,000 cu. ft. per minute at 10/15 lbs. per sq. in. and is driven through speed increasing gears by a 2,200 h.p., 770/580 r.p.m. D.C. motor. These motors derive their power from two 1,740 kW grid controlled rectifiers with additional and blowers now in course of construction for both home and overseas customers.

During the course of the year, a number of compressors have been put into commission in the South African Goldfields, one being a 15,000 cu. ft. set for the New Consolidated Goldfields for Luipaardsvlei Estates and G.M. Co. Ltd. This machine is driven by a 3,400 b.h.p. motor through speed increasing gears having a ratio of 1,500/5,400 r.p.m. and delivers at a pressure of 112 lbs. per sq. in. absolute. Other machines put into service include two sets for the Libanon Gold Mining Company, a 10,000 cu. ft. unit for the Premier Mine, and a 20,000 cu. ft. set for the Rand Leases Vogelstruisfontein G.M. Co. This last machine delivers air against an absolute pressure of 102 lbs. per sq. in. and is driven by a 4,100 b.h.p. motor through a set of increasing gears having a ratio of 1,500/5,120 r.p.m.

ENGINE-DRIVEN GENERATORS.

Many engine-driven generators are in course of construction for overseas customers. Two 900 kW sets, complete with the associated switchgear and transformers, are being built for Williamson Diamond Mines, Tanganyika, and 23 sets with an aggregate output of 2,250 kW for use in substations on the Assam Railways.

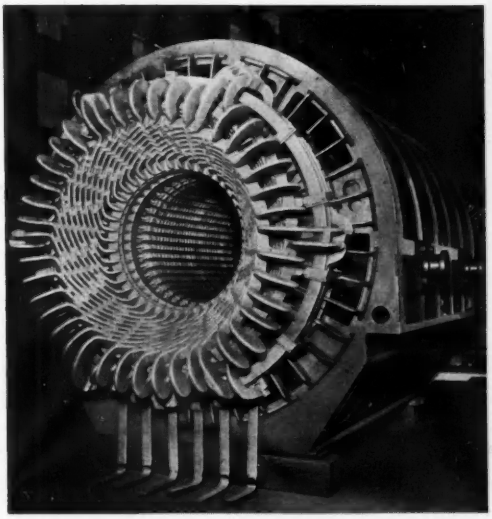


Fig. 2.—A wound stator for one of the turbo-generator sets for the Orlando Power Station, Johannesburg.

SYNCHRONOUS CONDENSERS.

An order has been received from the New South Wales Railways for three large synchronous condensers each rated at 20,000 kVA, 11 kV and designed to run at 1,000 r.p.m.

The machines will be used in conjunction with automatic voltage regulators for governing the voltage on the 66 kV side of the step-down transformers at Carlingford Terminal station, which is connected through a 132 kV transmission line to the generating station some 70 miles away.

Each condenser is capable of providing 21,800 kVA at 12 kV at zero lagging power factor, or 10,000 kVA at 10 kV at zero leading power factor. Starting is effected by direct coupled pony motors of the synchronous induction type. To maintain stability of excitation, a pilot exciter is employed which provides excitation both for the main and pony motor exciters.

TRANSFORMERS AND REACTORS.

The many large contracts now in hand for equipment for home use include a number from the British Electricity Authority for six 70,000 kVA, 11·8/140·7 kV generator transformers and six 45,000 kVA, 132/33 kV units. The generator transformers, on which forced oil circulation with air blast cooling is employed, are fitted with on-load tapping switches, and will be installed in the Uskmouth Generating Station.

Other important orders for generator transformers cover two 41,000 kVA, 11/36 kV units for the Huncoats Station and two 36,000 kVA, 11·8/70·8 kV units with on-load tapping switches for $\pm$ 7½ per cent H.T. voltage variation for Doncaster.

Export orders include six 16,000 kVA, 6·6/138 kV transformers for Spain and a 40,000 kVA transformer for Palestine. The latter unit is designed for a primary voltage of 10·5-11 kV and a secondary voltage of 105-115 kV and is fitted with an off-circuit tapping switch. Cooling is by means of forced oil circulation with water cooling for which purpose twin coolers are provided.

For the I.C.I. Yarraville, Australia, four 870 kW, 1,276 kVA transformers are being built for electrolytic duty and are designed for a 6·6 kV A.C. supply, giving a rectified output of

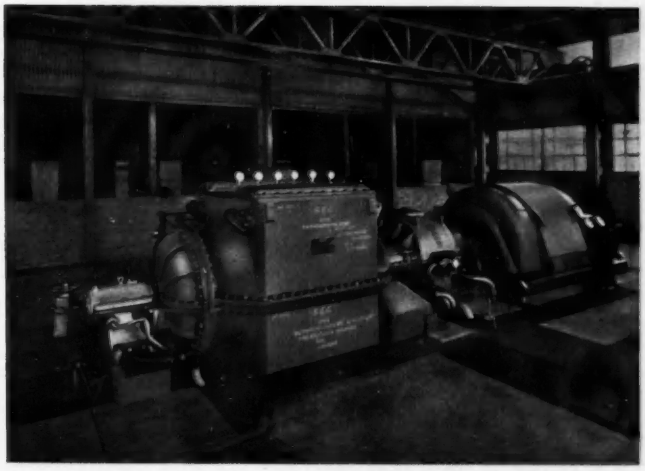


Fig. 3.—Motor-driven turbo-compressor at the Blyvooruitzicht G.M. Co., Rand Mines. The compressor is driven through speed increasing gears by a 3,935 h.p. motor.

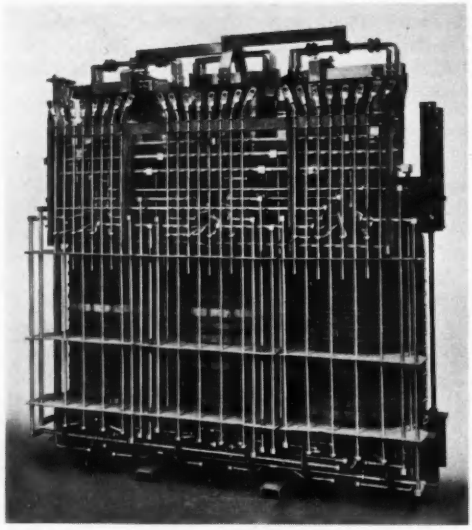


Fig. 4.—The wound core of a 2,400 kVA rectifier transformer for the Steel Company of Wales, showing the secondary connections.

200-250 volts, 3,840 amps. D.C. The secondary voltage is controlled by means of a 20 position on-load tapping switch on the primary side.

A special transformer for use in the testing of compressor motors is being built for the Fraser & Chalmers Works. The rating is 6,000 kVA continuous and 20,000 kVA for 5 minutes, the primary voltage being 22 kV. The secondary winding is arranged to give from 1·1 kV to 13·2 kV in twelve steps.

Six 1,600 kW, 2,400 kVA rectifier transformers for the Steel Company of Wales are nearing completion. They are designed for use with an 11 kV A.C. supply, the rectified output being 440 volts, 3,650 amps. D.C. The secondary connections are 12-phase with interphase transformer, and the primary connections enable two equipments to be operated in parallel to give equivalent 24-phase operation (fig. 4).

For the British Broadcasting Corporation, a special transformer has been completed for use with a high voltage steel tank rectifier. In this case the D.C. output is 100 kW at 10 kV and a switching arrangement is employed to enable a reduced voltage to be obtained for starting purposes.

Orders for the concrete type of reactor include four 3-phase banks for Glasgow Corporation suitable for use on 6·6 kV systems and rated at 6 per cent reactance at 1,750 amps. For Auckland there is being built a 3-phase bank of reactors of this type suitable for 5·2 kV and rated at 8·64 per cent, 500 amps.

A number of equipments has been completed for smoothing the D.C. supplies to cinema studio arc lamps. Noiseless operation is essential for such arcs in order to avoid the possibility of interference with sound recording. The filter serves to eliminate all superimposed A.C. ripple voltages from the D.C. generator voltage. The filters comprise coreless inductances of the air-cooled type and high value capacitors with fuses, the components being connected to form an aperiodic filter suitably arranged to deal with a range of frequencies (fig. 5).

The aid which electricity can give to the horticulturist is now generally appreciated and among its many uses that of soil warming is unquestionably one which has attracted keen public interest in recent years. The G.E.C. were pioneers in this application but for a long time some apprehension as regards electric shock and the vulnerability of the expensive heating elements were factors which hindered its progress. Under the supervision of the Company's Agricultural Department a range of small transformers has been developed, which are carefully designed to provide a safe low voltage supply and to operate under the inevitably damp and exacting conditions of the greenhouse, frame or exposed garden plot. The special features of these transformers can be conveniently summarised as follows :

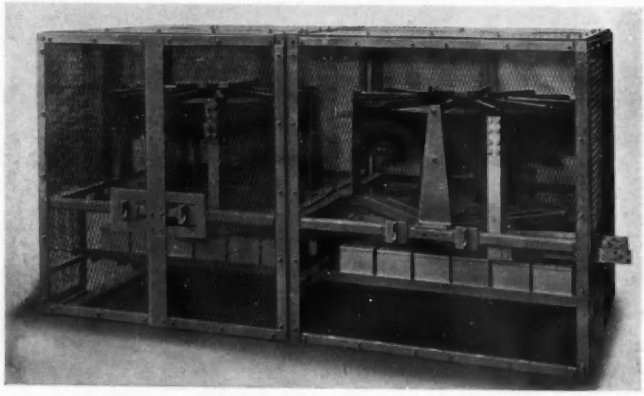


Fig. 5.—Arc noise suppression unit for cinema studio

(1) The output terminals are so positioned that risk of accidental short circuit is extremely remote.
(2) A suitable point of the output winding is positively earthed to ensure that the user is protected against dangerous voltages should an internal fault develop.

vibration and short circuit tests imposed by the Admiralty. Considerable research has been done on the electrical and mechanical properties of the special materials used and also in perfecting an impregnation process which will ensure reliable service from the product in any part of the world.

Fig. 6.—6·6 kV, 250 MVA metalclad switchboard installed in a substation in Birmingham.

(3) The smaller sizes, designed primarily to meet the needs of the amateur, have a completely sealed case; a flexible lead is provided for the connection of the primary to the mains. As a further protection against any possibility of breakdown between primary and secondary windings, the two are physically separate being assembled side by side and spaced, instead of being wound concentrically in the conventional manner. On the larger capacity units, where for technical reasons such an arrangement is impracticable, the coils are wound concentrically but have an earth shield interposed between them.
(4) The heater wires are of robust and durable galvanised steel fitted with spade terminals for connection to the transformer.

A large number of air-cooled transformers within the range of 1-15 kVA is in hand for the Admiralty and will be used to supply power for lighting, radar apparatus and other services on board ship. Special requirements include minimum weight, the use throughout of inorganic insulating materials and a type of construction capable of withstanding the very severe shock,

Metalclad Switchgear.

Numerous contracts for heavy duty metalclad switchgear have been completed and many further orders have been received. For Sydney County Council, fifteen 33 kV units are being supplied, while twenty-seven 33 kV units with bus zone protection are on order for Brisbane City Council. In addition, there are some thirty-nine units for the British Electricity Authority for installation at various power stations and substations throughout the country.

The new range of metalclad switchgear, rated at 150 to 350 MVA at 3·3 to 11 kV, to which reference was made in the review of progress in this Journal in January, 1949, has met with an encouraging reception and the circuit breakers have now been tested in accordance with both British and Canadian Standards. Among the many orders for this class of equipment for service in substations both at home and overseas mention may be made of thirty-three 6·6 kV, 250 MVA units for the State Electricity Commission of Victoria. Fig. 6 shows the first of this type of switchboard now in service in one of the Birmingham substations.

As regards heavy duty metalclad switchgear, 91 units are on order comprising eight substations. Fig 7 shows a 17-panel board for the South African Iron and Steel Corporation.

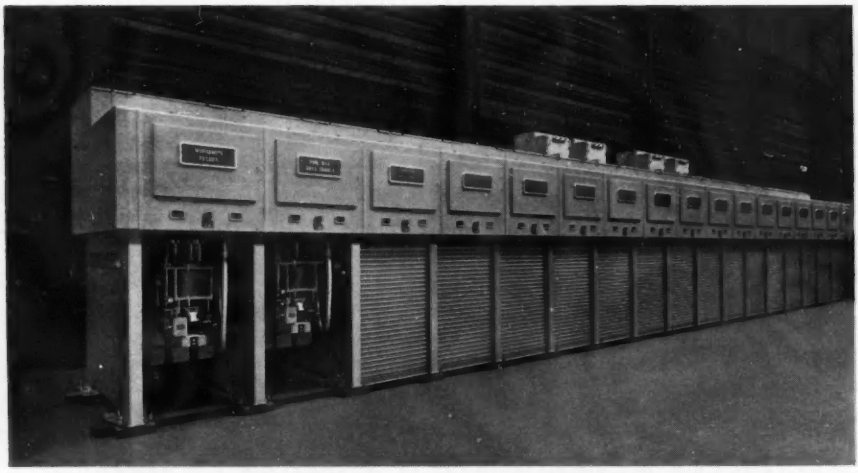


Fig. 7.—17-panel, 11 kV, 500 MVA heavy duty metalclad switchboard for the South African Iron and Steel Corporation.

Outdoor Equipment.

For switching stations overseas much equipment is being supplied which includes both oil circuit breakers and air-break switchgear. Among the more important of these are the three 66 kV stations for the Government of Nagpur, Berar, India, and the 33 kV switching station for the Uganda Electricity Board in connection with the Owens Falls hydro-electric scheme, the equipment for which includes twelve 750 MVA circuit breakers.

Fig. 8 shows one of a number of 66 kV breakers recently delivered to India. This breaker is fitted with compound-sealed condenser bushings; others on a recently completed contract had oil-filled bushings. Extensive precautions, including the fitting of heaters in the circuit breaker tanks and mechanism housings, make these breakers suitable for continuous service under monsoon conditions.

Cubicles.

The provision of additional plant in the Switchgear Works, in the shape of brake presses and turret presses, has enabled a complete range of standard cubicles of a new type to be introduced. These cubicles are built on the unit principle and can be used for all kinds of control boards, high voltage and low voltage switchboards, contactor panels and the like. The units of which they are constructed consist of flat panels made by bending into U section the edges of previously punched steel plates. In this way a construction of very neat appearance, requiring

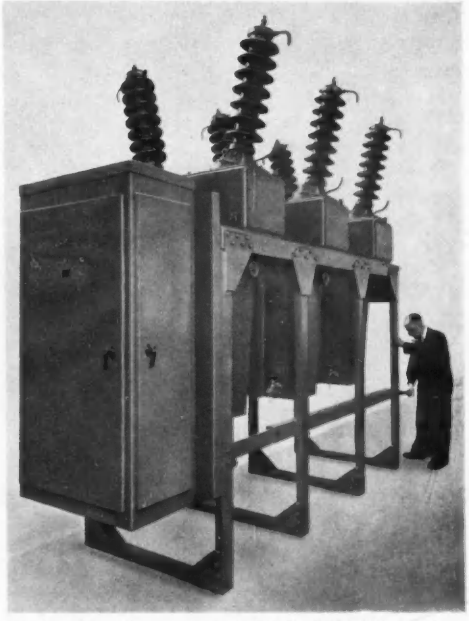


Fig. 8.—One of a number of 66 kV, 500 MVA, outdoor type, three tank, oil circuit breakers recently supplied to India.

no framework, is produced. The parts are fastened together by means of concealed bolts passing through holes punched in the internal flanges. Each unit panel has a large number of holes in standard positions which can be used not only for fixing the units together to form cubicles, but also for the attachment of the internal parts. In the case of contactor cubicles it is possible to mount the contactors and other apparatus on their slabs and then erect the cubicles round the slabs.

Front and rear doors can be supplied and, where necessary, the cubicles can be rendered dust proof. A typical cubicle board of the new type is shown in fig. 9.

Air-Break Power Station Switchgear.

Further progress has been made in the range of standardised air-break switchgear for voltages from 400 to 3,300 volts. This type of gear is finding increasing application in power stations both at home and abroad. The cubicles are designed on the unit principle so that sections housing circuit breakers, switches, fuses, contactor starters, rectifiers, transformers, measuring equipments and the like are of uniform size and appearance and may be built into complete switchboards.

Fuse Operated Circuit Breaker.

Where a very small supply has to be taken from high voltage busbars, for example in the case of an auxiliary transformer of, say, 5 or 10 kVA capacity connected to 33 kV busbars, the problem of adequate overcurrent protection is very difficult. The normal load current is so small that no reasonable overcurrent will actuate any form of current transformer operated relay or trip mechanism. To overcome this difficulty the arrangement shown in fig. 10 has been devised.

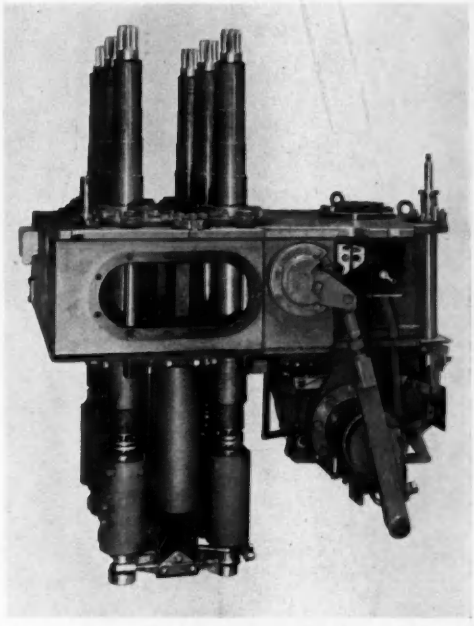


Fig. 10.—33 kV, 500 MVA circuit breaker of the fuse operated type. The fuse is mounted on the left of the moving contact cross arm.

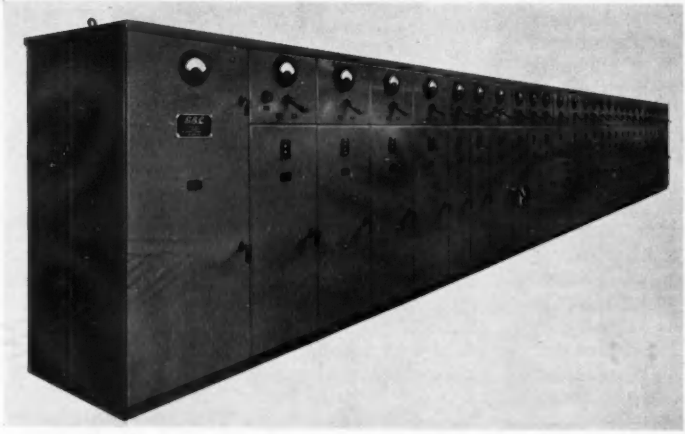


Fig. 9.—400 volt contactor board of the new construction for the mechanised foundry of Ideal Boilers Ltd.

The breaker is of standard construction, except that one of the moving contacts attached to the cross bar in each phase is insulated from it and connected thereto through a small spring loaded fuse. This fuse is set to operate at a suitable current and in so doing releases a spring which actuates a latch on the cross bar which in turn operates the trip gear through an insulating rod. The circuit is thus opened by the normal operation of the breaker and the fault current is interrupted by the arc control pots. During the time taken for the breaker

to open, which is only a few half-cycles, it would nevertheless be undesirable for the fuse to continue arcing. To prevent this, the fuse is shunted by a small spark gap designed to break down and weld up solid as soon as the voltage

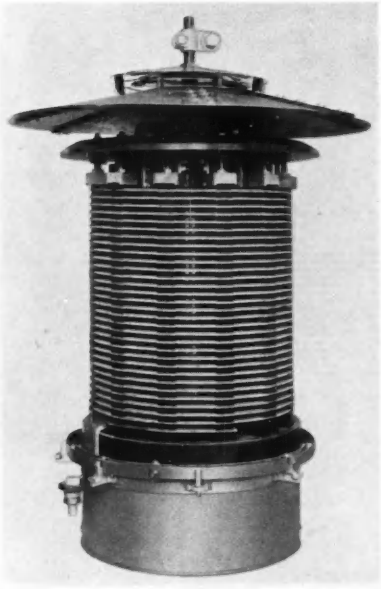


Fig. 11.—Trap choke coil, type CC mark V, 132 kV, 500 amps. with cover removed.

across it exceeds a few hundred volts. This means that, as soon as the fuse blows, the spark gap arcs across and thus carries the current until it is broken as described. The fuse and spark gap are replaced as a unit.

Power Line Choke Coils.

Power line choke coils have been produced to work in conjunction with high frequency carrier telecommunication and signalling equipment, manufactured by the Company's Telephone Works, wherein the circuits are superimposed on the high voltage power line. The coils are connected in the actual power line and must offer negligible impedance to the normal low frequency current of the feeder system. The coils serve two purposes : they block off high frequency carrier energy from those parts of the feeder system where it is not required; they also form part of a filter which couples the high frequency circuit to the power line. The coils are capable of carrying 500 amps. continuously and of withstanding a short circuit current equivalent to 2,500 MVA at 132 kV. A typical coil of this rating is seen in fig. 11.

New Range of Distribution Boards.

A new range of distribution boards has been produced with a very clean external appearance. The case is made of sheet steel without any projecting fixing lugs or unsightly hinge lugs. The door may be lifted off its hinges, and to make its replacement easier, one hinge pin is made longer than the other, so that it is not necessary to engage both at the same time.

The door fasteners are recessed into the door and may be operated with a screwdriver or a coin ; they may also be padlocked. The fuses fitted may be either rewireable semi-enclosed or the H.R.C. cartridge type ; the range covers 30, 60 and 100 amp. sizes. In fig. 12 is seen a 4-way, 100 amp. double pole board with the door detached.

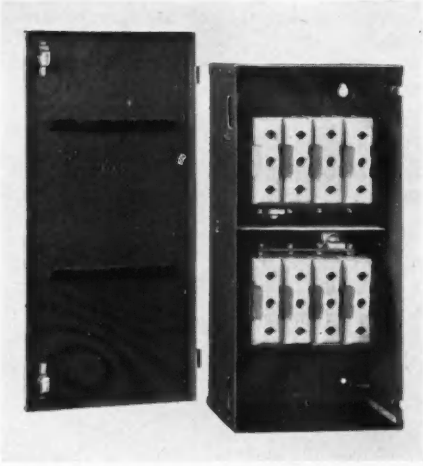


Fig. 12.—A 4-way, 100 amp. double pole distribution board with door detached.

Mercury Arc Rectifiers.

As pioneers of the air-cooled, steel tank, pumpless rectifier, the G.E.C. continues to hold its leading position in the design, development and application of new forms of this type of apparatus. Some details were given in the review of progress in this Journal in January, 1949 of rectifiers with additional anodes for supplying the fields of D.C. motors. Such equipment is finding increasing applications for variable speed motor drives. In addition to the 400 kW,

500 volt units supplying power for the electric drive of a cogging mill at the Kilnhurst Steel Works of John Baker and Bessemer, Ltd. (fig. 13), rectifier equipment of this type, aggregating 20,000 kW, is being built for the new power stations of the British Electricity Authority at Accrington and Uskmouth.

Hitherto it has been possible to meet the demand for 12-phase rectification only by using two 6-anode pumpless rectifiers. The double advantage of simplicity and compactness has now been achieved by the introduction of the 12-anode air-cooled steel tank pumpless type illustrated in fig. 14.

Reference was also made in the last review of progress to a small steel tank pumpless rectifier. Again in the interests of compactness this has now been produced in the form of a high tension rectifier but since the standard vitreous seals would be too bulky for this unit the Company has developed a new design of glass-to-metal seal of particularly robust construction suitable for an output of 10,000 volts D.C. A 100 kW equipment of this type has been supplied for broadcasting service which is considerably more economical of space than other designs (fig. 15).

Methods of manufacture are continually under review, particular attention having been given to the finer points of rectifier production. To mention only one improvement, a completely air-conditioned room has now been brought into service which affords a clean, dry atmosphere for the final stages of rectifier assembly.

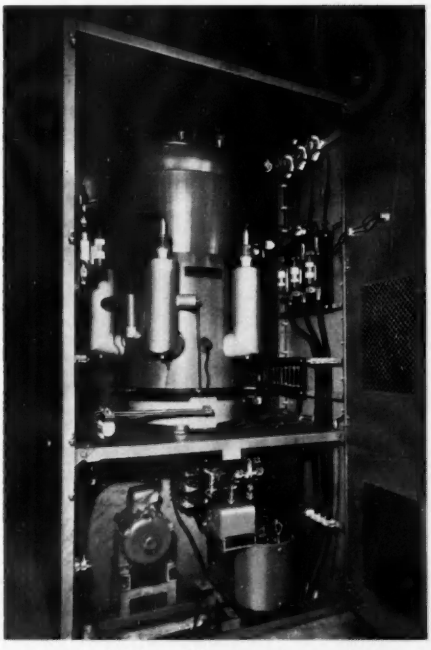


Fig. 13.—400 kW, 0 to 500 volt grid-controlled rectifier supplying power for the electric drive of a cogging mill at the Kilnhurst Steel Works of John Baker and Bessemer, Ltd.

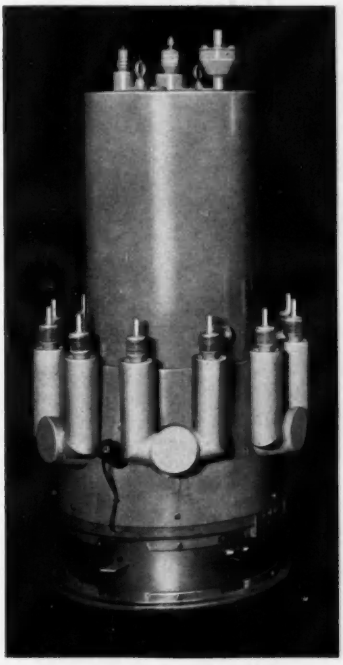


Fig. 14.—12-anode air-cooled steelclad rectifier.

Overseas orders continue to form an important part of the production programme. In addition to equipment for Belgium, Australia, Holland and New Zealand, the Company has received an order for a 1,700 kW rectifier plant for Canada ; this means that G.E.C. pumpless rectifiers will be in service in all the five continents.

During the year the 1,200 kW, 1,500 volt mobile equipments for the Netherlands Railways have been commissioned (fig. 16) and a further extensive contract is in hand for sixteen units of a similar rating for the re-equipment of railway substations in Holland. Other overseas orders include a 1,700 kW unit for The City of Edmonton, Alberta, six 500 kW units for Calcutta and two 350 kW units for the Colombo Tramways, Ceylon ; the last-named being the

first contract from that country for air-cooled rectifier plant.

At home the 1,500 volt equipment, with a total output of 30,000 kW for the railway electrification scheme between Liverpool Street and Shenfield has been put into service (fig. 17).

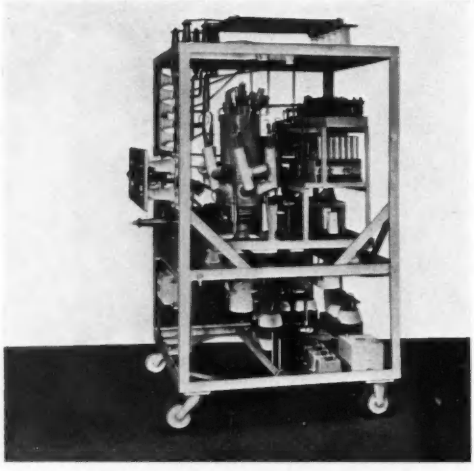


Fig. 15.—100 kW high tension air-cooled rectifier for the British Broadcasting Corporation.

Amongst interesting new applications, both in the home and overseas markets, mention may be made of the use of grid-controlled pumpless rectifiers for printing press drives, turbo-blowers and drawbenches, giving further evidence of the adaptability of this type of plant.

Cable Sheathing by Cold Pressure Welding.

A description of the method of cold pressure welding developed by the G.E.C. Research Laboratories has been given in a previous issue of this Journal[1]. This unique process lends itself very readily to the manufacture of aluminium sheathed cables, and the Pirelli-General Cable Works, in conjunction with the Research Laboratories, have constructed the machine illustrated in fig. 18 which is now ready for production.

The process can be divided into four stages : (*a*) flange forming ; (*b*) preparation of flange surfaces ; (*c*) introduction of cable and tube forming ; (*d*) pressure welding and cutting off the flanges. Aluminium strip of the required width is drawn into the rolls from the spool seen at the back of the machine. The rolls form the strip into a trough shape with two horizontal flanges. This troughed strip can be seen emerging from under the cowls housing two rapidly rotating steel scratch brushes which give the metal the necessary surface finish to enable the cold weld to be made. Two flexible suction hoses remove the dust abraded by the brushes which are adjustable to suit the width of the strip being used.

The cable to be sheathed is seen passing be-

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XVI, No. 1, January, 1949, pp. 50, 51.

Fig. 16.—1,200 kW, 1,500 volt mobile rectifier equipment on service on the Netherlands Railways.

tween the flexible hoses and is guided by the vertical roller into the troughed strip which then passes between the tube-forming rollers mounted on vertical axes on either side of the cable.

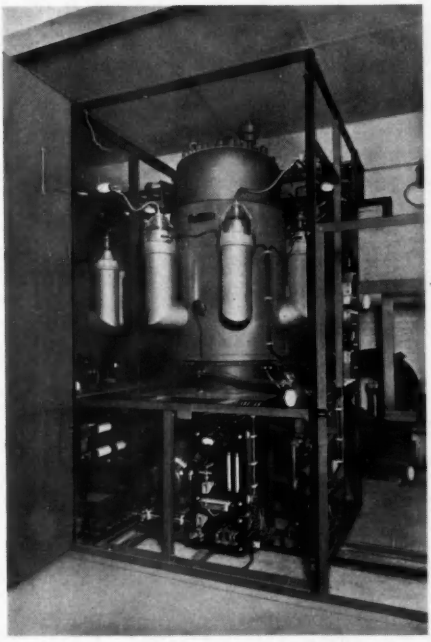


Fig. 17.—One of the two cylinders for a 1,500 volt, 2,000 kW rectifier equipment at the 8,000 kW Stratford sub-station, London.

Finally, the flanges are cold pressure welded in the last pair of horizontal rolls and the waste metal above the " nip " of the welding rollers is removed at the same time. Both the welding rollers in this pair are driven and provide the only source of drive throughout the machine, all the forming rollers running idle. The driving motor and gearbox are mounted below the machine which is so designed that the prepared surfaces of the flanges are kept absolutely clean and free from oil until welding has been completed.

To remove any roughness that may remain after the flange has been nipped off, the sheath passes through a final pair of vertical peening rollers seen in the foreground.

Sheathing is a continuous process and the aluminium strip used is joined when necessary by a method of brazing so carried out as not to interfere in any way with the welding process.

The machine illustrated is designed for the sheathing of power and telephone cables up to 1½ ins. overall diameter. Another machine is in course of development for sheathing the smaller type of cable and will be specially suitable for aluminium sheathed house wiring cables of the flat twin and other types.

Cables sheathed by the cold pressure welding process pass the appropriate bending tests and are lighter and mechanically stronger than their lead-sheathed counterparts ; there is little doubt that they will have a considerable field of usefulness. Any type of cable can be sheathed on the machine, including rubber and plastic, dry-core, mass impregnated, pre-impregnated or even oil filled cable, if required. An important feature of the process is the complete absence of heat during sheathing which enables some dielectrics to be sheathed which cannot easily be dealt with by the normal sheathing methods.

MINING GEAR.

The 1,350 h.p. and 1,750 h.p. geared A.C. winding equipments for the Welsh Navigation and Calverton units respectively of the National Coal Board have been put into commission in the course of the year just past. The 1,750 h.p. skip winder at Calverton which is being used for shaft sinking is seen in fig. 19.

The winder installed in the Welsh Navigation

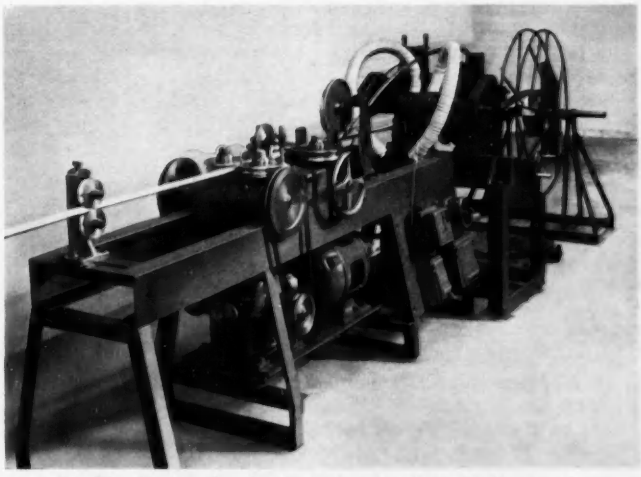


Fig. 18.—Machine for the aluminium sheathing of cables by the cold pressure welding process.

Colliery is of interest in that it is designed to hoist from two levels simultaneously. Under these conditions the out-of-balance load is very considerable and on this account dynamic braking is employed. A second and smaller winder rated at 700 h.p. has also been installed at this colliery and in this case, too, dynamic braking is used. The stator reversing contactors, D.C. contactors and the exciter set for the dynamic braking, which are similar to those for the larger winder, are seen in fig. 20.

Winding Engines

It is now some three years since the first oil-operated servo units and regulators manufactured by the Company were put into service as auxiliaries to electric winders for the purpose of operating the liquid controllers on a predetermined cycle. The rate of travel in one direction is variable in relation to that of the return stroke. These equipments proved eminently satisfactory and, as a result, it was decided to re-design the unit as a self-contained assembly so as to render it suitable for many other industrial applications.

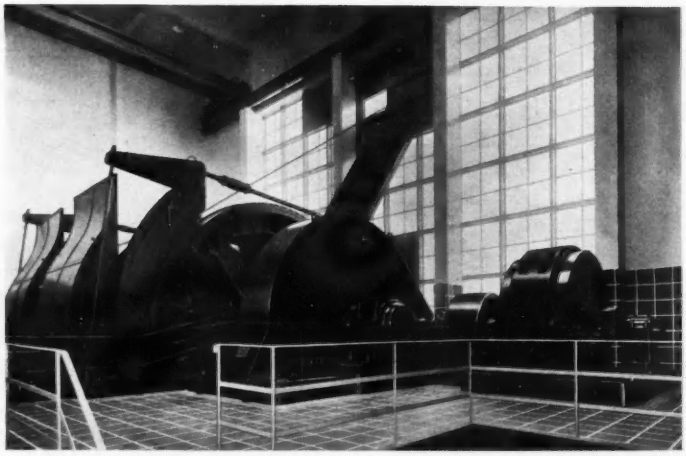


Fig. 19.—1,750 h.p. geared A.C. skip winder at the Calverton unit of the N.C.B.

The re-equipment programme of the N.C.B. has involved the manufacture of much flameproof gear and many orders for this type of equipment have been completed during the year. The range of flameproof motors has been still further extended.

Several large schemes are in hand for coal preparation plant, one being a comprehensive contract for the Nantgarw Colliery embracing the complete coke handling plant and the electrical equipment for gas producing and by-products plants. The aggregate horsepower of the various motors employed will amount to 2,600 h.p.

For Mansfield Colliery both the mechanical and electrical equipment are being supplied for a coal preparation plant. The motors involved aggregate 2,400 h.p. and are arranged for centralised control from 26 remote control stations, the complete sequence of operation being reproduced on a mimic diagram board.

Further information on this type of equipment is given in the section, Mechanical Handling, page 33.

The assembly now comprises a fabricated welded steel tank, partitioned in order to prevent oil surge and having a strainer and filter. The top cover is in the form of a platform on which is mounted the power cylinder assembly consisting of the cylinder, piston, rack, quadrant and regulating valve. The connections to the operating lever and liquid controller are external to the power unit, affording easy assembly and simplicity in maintenance.

The pressure oil required for operating the power cylinder is supplied by a vertical type geared pump having drowned suction and driven by a $\frac{3}{4}$ h.p. directly coupled squirrel cage motor.

The motor runs continuously while the unit is in operation, the oil being by-passed back to the tank through a relief valve when the cylinder is stationary. Variable piston speed is obtainable by adjustment of the regulator valves, and it is possible to vary the rate of travel at different positions during the stroke both in the forward and return directions.

The recently manufactured unit is designed to have a variation in piston speeds of from 6 to 50 ft. per minute and develops a thrust of 350 lbs. in either direction.

ROLLING MILLS.

Much of the electrical equipment for the Abbey Works of the Steel Company of Wales is now on site and includes some of the mercury arc rectifiers and many of the D.C. mill type motors (fig. 21). So far, the number of motors of this type on order for the plant exceeds 1,000, with outputs ranging from 5 to 200 h.p. Further orders for this very extensive works continue to be received ; recent contracts include a 1,000 h.p. slab squeezer motor, a 300 h.p. crop shear motor and roller table motors with the associated motor-generator set and control gear, as well as the complete electrical equipment for two skin pass mills, the main mill motors for which are rated at 700 h.p. and 400 h.p. respectively. In the larger installation, the mill and reel motors are supplied from a 1,150 h.p. motor-generator set, the control equipment embodying cascade exciters. For the smaller mill the main motor is supplied from a grid controlled rectifier. An equipment of this type has recently been commissioned at the steelworks of John Baker and Bessemer, Ltd (fig. 13) where speed control of a cogging mill is obtained from the grid controlled rectifier.

A considerable amount of equipment is also on order for Richard Thomas & Baldwins, Ltd., For the Scunthorpe works a 5,000 h.p. cogging mill drive and a 3,000 h.p. Ilgner set are required; at the Brierley Hill Works a Cluster Bliss mill is to be converted to a strip mill for which the electrical plant includes two 800 h.p. reel motors supplied from a 650 kW motor-generator set, a 100 kW drag generator and two boosters.

Many extensive orders continue to be received for mill equipment from overseas customers both in the Commonwealth and in continental Europe. Much equipment has, in the past, been

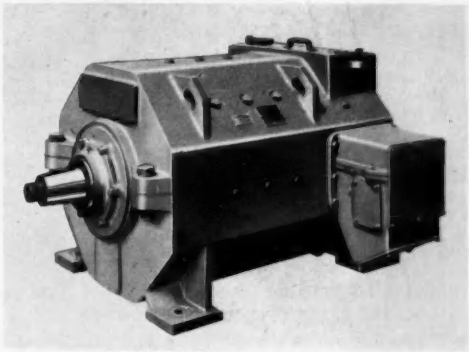


Fig. 21.—150 h.p. steelworks motor for the Steel Company of Wales.

supplied to the Australian Iron and Steel Company from whom an order has now been received for the electrical equipment of a two-stand temper mill. The main mill motors are rated at 1,000 h.p. and are supplied from two motor-generator sets ; in addition the contract includes all the auxiliary motors and associated control gear.

From Devilley & Camion, Belgium, there is an order for the complete electrical equipment for a cold reversing mill for which the main motor is rated at 250 h.p.

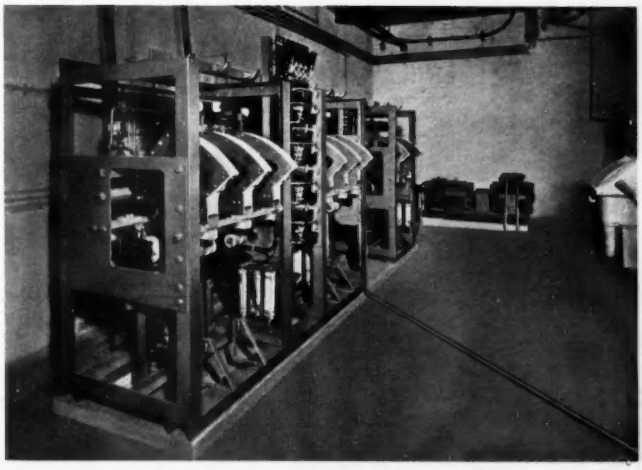


Fig. 20.—Stator reversing contactors, D.C. contactors and exciter set for the dynamic braking of the 700 h.p. winder at the Welsh Navigation unit of the N.C.B.

CASCADE EXCITERS.

Many industrial drives, of which those in modern rolling mills are outstanding examples, demand a control system which combines the advantages of speedy response, high sensitivity and complete stability. To meet these requirements the cascade exciter system has been adopted for many of the rolling mill equipments now under construction.

The cascade exciter, as the name implies, is composed of two or more machines in cascade. It has been designed to provide

rapid operation and considerable change in output for a very small change in its field current, such an exciter being most useful in closed-loop servo-mechanisms. Apart from its laminated field circuit, the cascade exciter does not differ from an ordinary D.C. machine either in principle or structure. It is no more difficult to maintain, and produces the required rapidity in response and sensitivity without introducing complications associated with other exciter systems of comparable performance.

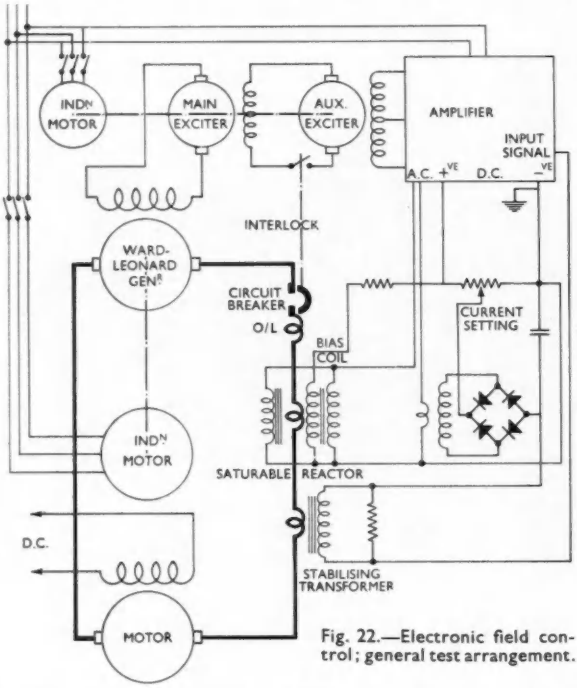


Fig. 22.—Electronic field control; general test arrangement.

The most rapid response and accurate results are obtained by exciting the first exciter from an electronic amplifier ; this apparatus contains a number of standard valves having a life of about 15,000 hours. The required input signal to the amplifier is very small indeed. In fact, approximately 1 volt fed into a resistance of 1 megohm will produce four to six times the normal working voltage of the exciter and thus force the flux in the field of the main machine to the required value in a minimum of time.

A very accurate voltage, speed or current control can thus be obtained, and, in addition, overriding controls can be included. As an example, a voltage control with a current limit will enable a very accurate control of voltage to be maintained until the current in the controlled circuit reaches a predetermined value, and any further increase in current is prevented by the current limit control taking charge over the voltage control.

The diagram in fig. 22 shows a typical current control circuit. The motor to be controlled is seen in the lower left-hand corner, and has a constantly excited field. Just above is the Ward-Leonard set, the generator field of which is controlled by the cascade exciter. This comprises main and auxiliary exciters, the field of the latter being energised by the electronic amplifier.

The input signal to the amplifier is the difference between the outputs of the saturable reactor or D.C. current transformer and the preset current control regulator, which are arranged in opposition. Thus any difference between these two voltages will operate through the whole chain of apparatus to alter the current in the main circuit until a state of balance is reached. The stabilising transformer adds a voltage to the input signal only when the current in the main circuit is changing, and thus prevents hunting.

If the requirements of accuracy and speed of response are not too exacting, a satisfactory performance can be obtained without the inclusion of the electronic apparatus. To do this, the various signal voltages, including feedback to prevent hunting, are applied to a number of separate field windings on the first exciter. As the output of this machine is small compared with its size, there is ample room for the required number of field windings.

INDUSTRIAL ELECTRIFICATION.

Grain Elevators.

A comprehensive description of the electrical equipment for some of the most important terminal grain elevators in Argentina was published in this Journal in April, 1949. A contract is now in hand for the whole of the electrical equipment for a 150,000 ton plant to be built in the Port of Buenos Aires. Motors aggregating more than 6,700 h.p. are being supplied, as well as transformers, switchgear, lighting and telephones. When complete, this plant will be the largest of its kind in the Southern Hemisphere. For a smaller grain storage plant at Santa Fé, motors totalling some 1,500 h.p. and their associated control gear are on order.

TIN MINING.

The resumption of tin mining in Malaya has been responsible for a heavy demand for electrical plant and control gear for tin dredgers and during the year orders for complete equipments for 5 dredgers have been received.

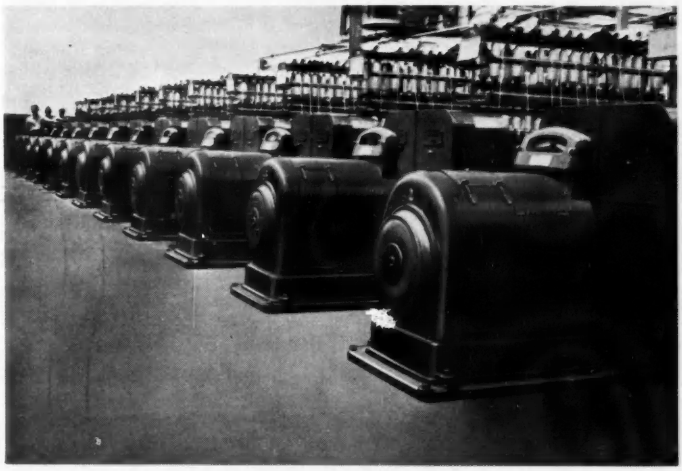


Fig. 23.—12/6 h.p., 1,200/600 r.p.m. variable speed automatic ring spinning frame motors at Misr, Kafr-el-Dawar, where 144 of these motors are in service.

PAPER MILLS.

For the Australian Paper Manufacturers Ltd., to whom large numbers of motors have already been supplied, contracts are in hand for a further 93 motors for various mills, ranging in size from 10 h.p. to 350 h.p. and with an aggregate output of some 5,000 h.p.

TEXTILE ELECTRIFICATION

As had been expected, the introduction of the new design of A.C. variable speed ring spinning frame commutator motors has aroused considerable interest and this has been followed by a big demand for the machines from overseas customers. Numbers of them are already in service ; fig. 23 shows part of an installation in a cotton mill at Misr, Kafr-el-Dawar, Egypt. The performance of these motors has fully justified the claims made for them in the matter of improved production. With the constant speed ring spinning frame it was not possible to maintain constant tension on the yarn which inevitably contained faults. On the other hand, variable speed spinning enables uniform yarn tension to be maintained, thus producing an even yarn, firm package and a minimum of broken ends.

Some years before the war Bansberia Jute Mill No. 2, owned by the Ganges Manufacturing Company, Ltd., was electrified throughout by the G.E.C. As a result of the operating experience thus gained, it has been decided to change over No. 1 mill from steam turbine to electric drive. The mill is situated on the banks of the Hooghli River, near Calcutta, and will receive a 6·6 kV supply from the Gourepore Electric Power Company's station some 5½ miles away on the opposite bank of the river. The electrical equipment will comprise all the switchgear and the necessary step-down transformers to supply the main mill motors at 3·3 kV and the auxiliary drives at 420 volts.

Fig. 24.—Lancashire weaving shed converted to individual drive.

The aggregate of all the motors will amount to 1,800 h.p.

At home the recognition of the advantages of individual loom drive has continued to create a steady demand for loom motors and many sheds in the Lancashire area are now completely re-equipped in this way. The benefts resulting from the elimination of overhead line-shafting and belting are now too well known to need any detailed description. The reduction in noise,

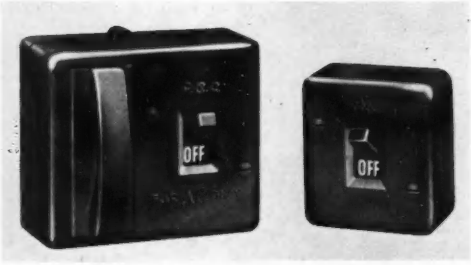


Fig. 25.—30 amp. bakelite tumbler switches for A.C. use, with and without fuses.

the lessening of dust and the unobstructed entry of light are, perhaps, the most important, besides the fact that the failure of any one machine does not affect the operation of all the others in the mill. An old-established mill recently converted to individual drive is seen in fig. 24.

A.C. Switch.

The 30 amp., slow break, short gap switch for A.C. only is of the all-insulated, double pole type, illustrated in fig. 25, and embodies the same basic principles as the range of "Mutac" switches, except that a bow spring bearing on an outer dolly cam to secure exceptional silence is not included. It is considered that the place where such switches will be fitted or the service required of them on power circuits will not ordinarily demand complete silence.

The heavy silver-faced spring contacts are operated by the cam of the dolly in the same way as those of the "Mutac" switch, and the normal speed of separation is calculated to obtain full gap, ·062 ins. (1½ mm), in a quarter to half a cycle. An "on" and "off" indicator is visible through the dolly aperture in the cover, the characters being in white on a red and black ground respectively. This indicator is sprung into position on the dolly and cannot fall off when the switch cover is removed. The cover completely encloses the base and is secured by two instrument headed captive screws. The switch is available either with back entry or front entry terminals and a drilling template is provided for the use of the wireman.

The 30 amp. switch fuse is a further development which incorporates an H.R.C. fuse which engages with jaws permanently fitted in the moulded base. This fuse was described in a previous issue of this Journal.[1] Like the standard switch, this unit is provided with back or front entry terminals, and an insulating plate is riveted to the underside of the base to cover all contacts to the fuse.

TRANSPORTATION.

The renewed activity in the field of electric traction, which has been particularly noticeable in recent years, continues, and is reflected in the orders for electrical equipment for all types of road and rail vehicles. In many cases repeat orders have been received in connection with the extension of existing projects. It is encouraging to note that the overseas demand for electric traction equipment shows no sign of slackening.

Trolley Buses.

The 94 trolley buses for Belfast Corporation which formed the subject of an article in the *G.E.C. Journal*, July, 1949, have now been

[1] *G.E.C. Journal*, Vol. XV, No. 1, p. 10, February, 1948.

Fig. 26.—One of the Cardiff Corporation trolley buses.

completed and are all in service. Further trolley buses of a similar type have been built (fig. 26) for Cardiff Corporation. The contract covers equipments for 75 vehicles, of which 25 have been delivered and have gone into service.

The equipments for Launceston and Hobart, Tasmania, have now been completed and have been followed by a further order for 12 equipments for Hobart from British United Traction Ltd., the makers of the chassis. The motor rating is 125 h.p. on a one-hour rating. The machines are of the compound wound, self-ventilating type arranged for rheostatic braking. They are capable of propelling the buses at speeds up to 40 m.p.h. The control gear is of the all-electric type, the motor current being handled by contactors actuated by a foot-operated master controller. In addition to electric braking compressed air brakes are provided, the foot brake pedal being so arranged that the first part of the stroke applies rheostatic braking, by operating the braking master controller, and this is followed, on further depressing the brake pedal, by the action of the air brakes.

The bodies are of the single-deck type and are being manufactured in Australia. All the trolley buses supplied to Tasmania have B.U.T. chassis fitted with G.E.C. electrical equipment; when the present orders have been completed some 93 buses will have been supplied.

The first model of an entirely new form of electric brake developed and patented by the Company for use on trolley buses is nearing completion and will shortly be installed for trial on a bus on the system of the Reading Corporation.

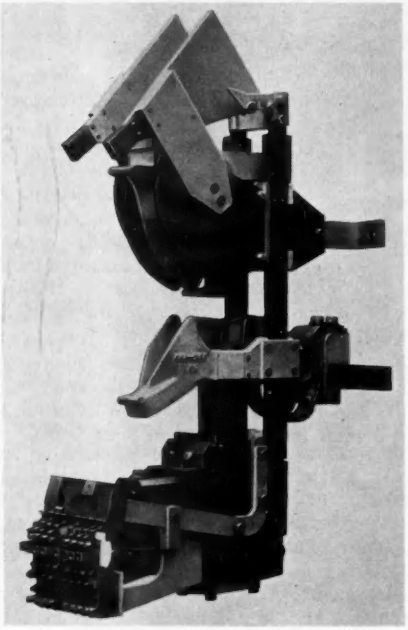


Fig. 27.—1,500 volt, 600 amp. traction type electro-pneumatic contactor, with arc chute removed and pole plates raised.

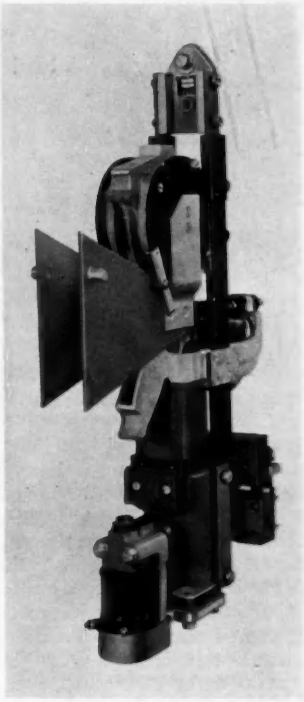


Fig. 28.—Main electro-pneumatic contactor for the locomotive supplied to Sociedade Estoril, Portugal, with the arc chute removed.

Railway Electrification.

The year has seen considerable new development in connection with 1,500 volt and 3,000 volt locomotive equipment. The electrical equipment for the 40 main line locomotives ordered by the South African Railways and Harbours Administration from the North British Locomotive Company is now in course of construction.

Other development already completed includes the design of heavy duty 1,500 volt contactors for locomotives having hourly ratings well in excess of 1,000 h.p. Fig. 27 shows this

contactor with the arc chute removed and the pole plate swung up for inspection. In this illustration can be seen the finger type interlock which is still preferred by many operators; others are adopting the totally enclosed silver-faced butt type contactor which will be used on the equipment for the South African Railways.

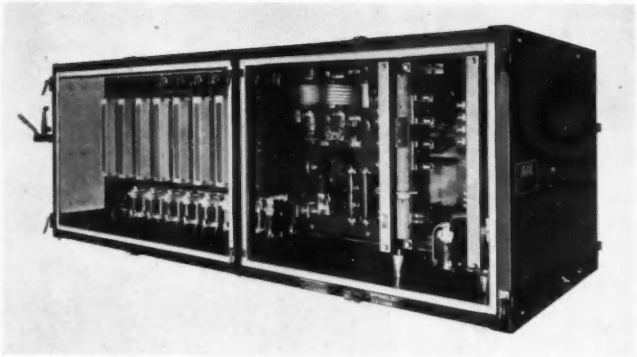


Fig. 29.—Under-car apparatus case for coaches on the Estoril Railway, with covers removed.

Progress has been made in the development of a new range of light and heavy duty pantographs. The light duty pantograph, developed since the war, is being used on the Estoril Railway, Portugal, both for the locomotive and the motor coaches. The new heavy duty pantograph will be fitted to the South African locomotives.

As mentioned in the *G.E.C. Journal*, January, 1949, the 1,500 volt locomotive for the Estoril Railway is of the double 2-axle bogie type, the four driving motors having an aggregate hourly rating of 960 h.p. Fig. 28 illustrates the main electro-pneumatic contactor with the arc chute removed and represents the latest design for this class of equipment. The electrical equipment for the coaches has now been completed and tested. Fig. 29 shows the apparatus case, which is mounted on the underframe of the coaches, with the covers removed.

The order for 156 motors of a new design for the surface stock of the London Transport Executive is nearing completion and a repeat order for a further 94 motors has been received. Before the war the Company supplied more than 800 motors for the Northern Line of the L.T.E. and these have now been in service for more than 10 years and have given complete satisfaction. An order for 54 additional motors of this type has now been placed.

The 3-car units for British Railways to operate on the electrified section between Manchester and Glossop will use the light weight pantograph already mentioned. The main electro-pneumatic contactors, which are a post-war development, have to deal with 1,800 volts and currents well above 4,000 amps., since, in association with relays, these contactors have to function as circuit breakers.

A number of diesel-electric shunting locomotives are on order for the Ceylon Government Railways. They will be of the 2-bogie, 4-axle type, each axle being driven by a 107 h.p. motor through self-contained double reduction gearing.

A combined main and auxiliary generator unit will be used on these locomotives with the auxiliary generator overhung on the shaft of the main machine. The four axle-hung traction motors, connected in parallel, are supplied from the main generator. The auxiliary generator provides power for the radiator fan, fuel transfer pump, priming pump and exhauster motors as well as charging the battery for the control circuits, starting and other services. Automatic control is provided between the engine governor and generator field rheostat which ensures that the engine will not be overloaded. The result is a finely graded control of speed and tractive effort well suited to the duties the locomotives are designed to perform. In an emergency it is possible to start the diesel engine by motoring the generator from current supplied from the traction motors while the locomotive is mechanically propelled.

Vehicle-actuated Road Signals.

A comprehensive article on special aspects of this subject appeared in the last issue of the *G.E.C. Journal*[1] and it is appropriate to mention that the Autoflex system was the pioneer of pneumatic vehicle detection in Great Britain.

With the continued growth of road traffic, the efficiency of road signalling systems becomes increasingly important. It is thus of interest to record that, as the result of recent developments, a new type of detector has been produced which affords greater sensitivity combined with some novel constructional features conducive to longer life under present-day conditions.

[1] "Vehicle-Actuated Road Traffic Signals," by H. I. N. Riddle, Siemens and General Electric Railway Signal Co., Ltd. *G.E.C. Journal*, Vol. XVI, No. 4, October, 1949.

Both the mat and the contact box in the latest detector are of entirely new design. Increased sensitivity is derived from the technical simplification obtained by using an electrical interlock to prevent actuation of the signals by vehicles crossing the mat in the wrong direction. Previously this was achieved by arranging the vanes in the contact box, which are deflected by air pressure impulses from the mat, in such a way that if what should be the second vane to operate were raised first, it prevented the first vane from lifting sufficiently to make the electrical circuit

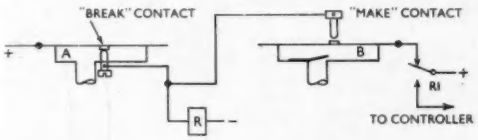


Fig. 30.—Construction of diaphragm chamber in the pavement-mounted contact box and electrical interlocking circuit.

to the controller. The new contact box is similar in shape and size to the former type and consists of an outer and an inner casting, the latter accommodating the diaphragms and contacts. In fig. 30 the diaphragms and their chambers are lettered *A* and *B*, the former diaphragm being the first to be actuated by traffic passing in the proper direction. The contact of diaphragm *A* is normally closed but breaks on the application of air pressure. A very small gap suffices to interrupt the current, which

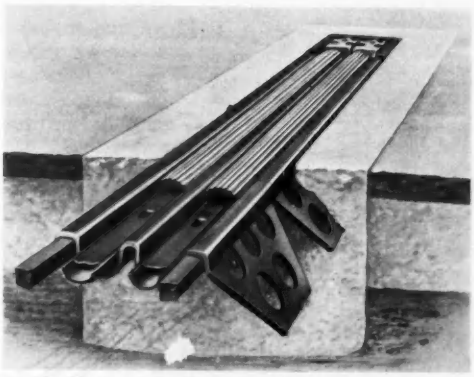


Fig. 31.—Diagrammatic view of mat framework embedded in concrete.

is only a few milliamps., so that the arrangement is highly sensitive; the absence of any mechanical stop other than the contact itself eliminates the effects of wear and results in the same amount of movement of the diaphragm always sufficing to interrupt the circuit. Diaphragm *B* carries a " make " contact and its chamber is provided with a triangular rubber non-return valve so that, after being deflected by an air pulse, the diaphragm is delayed about 1/40 sec. before returning to its original position. An interlocking relay *R* is associated with each contact box, and may be located in the control pillar or the contact box. The interlocking action can be followed from the diagram. A vehicle proceeding in the normal direction first actuates diaphragm *A* thereby de-energising *R* and causing relay contact *R*1 to reverse and send an electrical pulse to the controller. No effect follows from the immediately subsequent operation of diaphragm *B* and closure of the " make " contact, the circuit through *R*1 having been broken. However, if diaphragm *B* is actuated first, a second circuit is made through *R* and when the normal circuit is broken by *A* the relay remains energised, *B* not having had time to return to its " break " position by reason of the air held in the chamber by the non-return valve. By the time *B* breaks contact, *A* has been restored and maintains the feed to *R*.

The slightly lower sensitivity of the " make " contact compared with the " break " arrangement of the first diaphragm is adequate for its purpose, because only motor vehicles are likely to pull over to the off-side of the road far enough to traverse a mat in the wrong direction. However, in practice it is found that the normal bicycle and rider are heavy enough to make the diaphragm respond and so prevent a false demand signal being sent to the controller. Sensitivity to vehicles passing in the normal forward direction is such that the lightest cyclist registers with front and rear wheels even though the tyres may be partially deflated.

The mechanical construction of the new mat (fig. 31) affords a number of important advantages : its narrow width prevents the rubber bearing the full weight of a vehicle which is partly supported by outside flanges and the " nose " between the channels, at the same time the rolling or skidding of wheels is restricted in their tendency to force the tubes out of their channels. Moreover, when necessary, a tube can be removed for inspection and replaced inside half an hour. Grit and dirt are retained in sumps at one end of the boxes for subsequent removal.

Signalling Equipment.

In the autumn of last year the Eastern Region of British Railways brought into use an all-electric relay interlocking control system in the new

signal box at Liverpool Street Station, London, terminus of the main line to East Anglia and of the recently electrified Shenfield suburban services. The former semaphore signalling has been replaced by colour-light signals with roller-blind type route indicators at many locations (fig. 32).

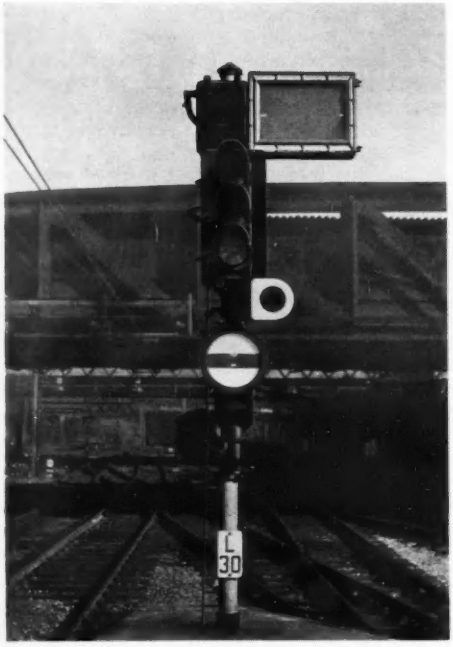


Fig. 32.—Three-aspect colour light signal with blind type route indicator and short range banner signal.

The whole of the relay interlocking equipment in the new signal box, the colour-light signals and point motors, A.C. track circuit apparatus and signalling power supplies installation were provided and installed to the requirements of the Signal and Telecommunication Engineer, Eastern Region, by the Siemens and General Electric Railway Signal Company. Resignalling by the Company has been carried out as far as Bethnal Green, where a second relay interlocking equipment has been provided. The new box at Liverpool Street replaces five former manual signal boxes, and that at Bethnal Green takes the place of three. The signalling panels are worked on the route-setting system, a route being set up by rotating a numbered disc and operating a small switch which forms part of the selector assembly. The point movements follow automatically and the appropriate signal aspect changes, provided there is no conflict with other routes already set up. If a conflicting movement is attempted, the relay interlocking prevents the signals being cleared and the points from operating until the move taking precedence has been completed. On the Liverpool Street and Bethnal Green installations 24 volts D.C. is used for relay interlocking, 110 volts D.C. for the point motors, 110 volts A.C. for the point relays and track circuits, and 12 volts A.C. for signal lighting.

In addition to the switchgear, rectifiers and transformers required for the installation, the Company has provided the train describers for all signal boxes from Liverpool Street to Romford.

Some interesting statistical details of the Liverpool Street-Bethnal Green installation are given below :

Colour-light signals	74
Subsidiary signals ...	100 (37 with associated route indicators)
Point machines	148
A.C. track circuits	220
Individual train routes controlled ...	368
Number of signalling relays	2,000
Outdoor cabling	581 core miles
Indoor wiring	80 miles

MARINE ELECTRICAL EQUIPMENT.

The single screw oil tanker " San Silvestre ", built by the Furness Shipbuilding Co. Ltd., for the Eagle Oil Shipping Co. Ltd., for which the G.E.C. supplied the complete electrical equipment, has now terminated her trials and is in commission. The main turbo-alternator set on this ship is seen in fig. 33. Similar equipment for a sister ship is in course of construction. The Blue Star liner M.V. " Melbourne Star " is now also in commission. The main generators, plural starting equipment and engine-room auxiliary motors have been supplied for this vessel and similar equipment is being built for four further ships for the same owners, one building at the yards of Cammel, Laird & Co. Ltd., one at John Brown & Co. Ltd. and two at the Fairfield Shipbuilding and Engineering Co. Ltd.

Plural starting gear for controlling 24 engine-room motors, ranging from 11 h.p. to 55 h.p., has been supplied for the P. & O. liners " Himalaya " and " Chusan " ; further ships of this line will in due course be fitted with similar equipment.

The overhaul of the " Rangitiki " and " Rangitata " of the New Zealand Shipping Co. Ltd. has been completed and the ships are now back in commission ; during overhaul the whole of

the original electrical equipment was reconditioned under the Company's supervision.

The new passenger liners " Rangitane " and " Rangitoto " have been fitted with lighting installations designed by the G.E.C. in which use has been made of both cold cathode fluorescent tubes and tungsten filament lighting.

The P & O liner " Strathmore ", refitted by Vickers, Armstrong Ltd., has now gone into service. The Company equipped this vessel with completely new lighting fittings and has also supplied a 500-line manual and a 100-line automatic telephone system. The " Strathnaver ", refitted at Harland and Wolff, carries similar equipment.

For British Railways, Southern Region, seven portable motor-generator sets have been supplied for dock use to provide a source of electric power to ships in port. Each equipment comprises a 50 kW motor-generator set and control gear mounted in a trailer so as to be readily transportable. The sets are driven from the shore supply and provide D.C. power at 110 and 220 volts.

ELECTRIC MOTOR DEVELOPMENTS.

D.C. Motors.

As a result of considerable development work, modifications have been made in the design of totally enclosed, fan cooled D.C. motors which have enabled the output of these machines to be increased from 10 to 15 per cent, depending upon their speed. These motors are specially designed for service in dust-laden atmospheres and can also be made watertight. They are built in sizes ranging from 4 h.p. at 1,000 r.p.m. up to 200 h.p. at 750 r.p.m.

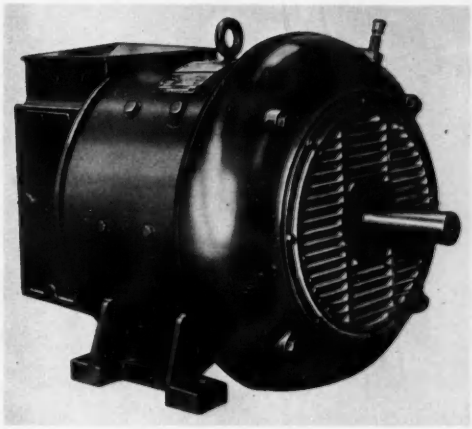


Fig. 34.—A new design of totally enclosed fan cooled D.C. motor.

In the new design, fig. 34, the silicon alloy cooling diaphragm is incorporated in the end shield bearing bracket at the driving end, thus affording an increased cooling surface and making possible the use of fans of larger diameter. The arrangement of the cooling diaphragm is shown

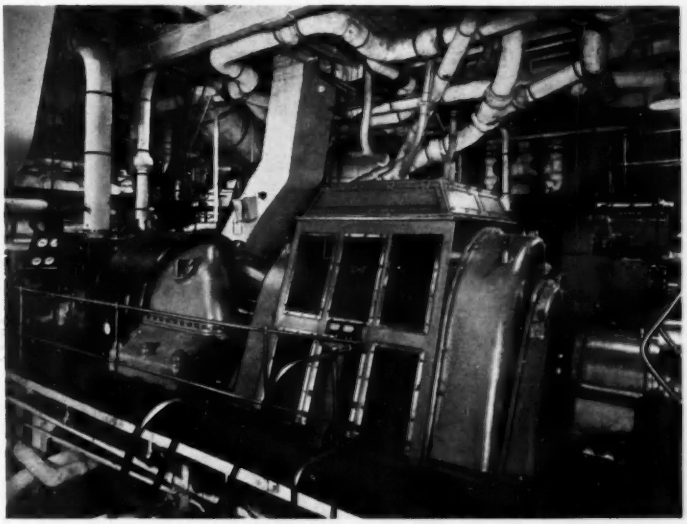


Fig. 33.—The main turbo-alternator on the T.E.S. " San Silvestre ".

in fig. 35. Two fans are provided, one of which circulates air within the motor, the other, which is mounted outside the diaphragm, blows cool air through the ducts, after which it is directed by a cowl over the field frame of the machine.

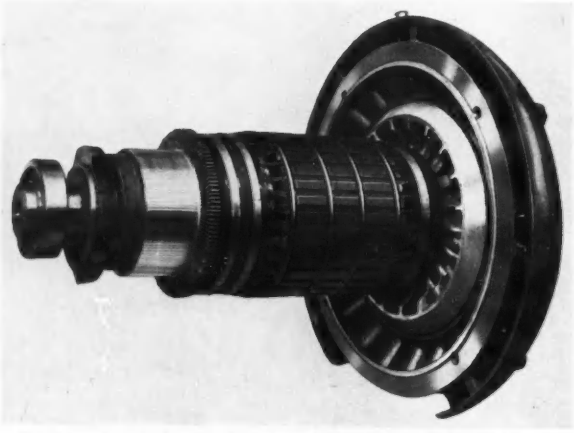


Fig. 35.—Arrangement of cooling diaphragm and internal fan for the new design of totally enclosed D.C. motor.

Internal baffles ensure that the air inside the machine is compelled to follow a definite path throughout the length of the motor.

FANS.

Developed primarily for domestic use, at home and overseas, the new moderately priced 8 in. A.C. table fan (fig. 36) employs pressure die castings for the base and for the motor housing which contains a totally enclosed shaded pole induction motor running at 2,250 r.p.m. The use of a rubber blade has made it possible to dispense with the guard and so achieve a pleasing continuity of outline. The carefully designed curvature of the rubber blade provides sufficient rigidity to produce an air displacement of 700 cu. ft. a minute ; at the same time it is flexible enough not to damage the hand if it accidentally comes into contact with the blade while it is rotating. This fan, which can also be used for wall mounting, is finished in silver grey and is provided with an " on " and " off " push button switch in the front of the base and 6 ft. of three-core cable.

Another new table and bracket fan developed during the year is the 16 in. A.C. oscillating model (fig. 37). Here again the appearance has been very greatly improved by the introduction of a new type of metal blade which has made it possible to eliminate the front, or cage-like portion, of the guard, leaving only a " frame " to protect the outer edges of the vanes. The new blade is most ingeniously designed so that the leading edge of each of the wide vanes is overlapped, and thus completely shielded, by the trailing edge of the vane in front of it. Consequently accidental touching of the rotating blade cannot cause an injury to the hand. Moreover, the new blade is quieter in operation than that of the more conventional table fan. A further improvement in appearance has been achieved by the use of a new totally enclosed motor modelled on aerodynamic lines in which the oscillating mechanism, now also totally enclosed, is situated at the *front* of the motor so that it is neatly tucked away out of sight immediately behind the fan blade.

The fan is supplied with a choke type regulator mounted in the base which provides three speeds and an " off " position. The whole is finished in a pleasing shade of old gold. Both fans are now in course of production and will be available in the spring.

FRACTIONAL HORSEPOWER MOTORS.

The Fractional Horsepower Motor Department has developed a new drink mixer (fig. 38)

Fig. 36.—New A.C. table fan.

which shows many improvements on existing designs. Die castings are used both for the supporting pillar and the motor casing which harmonise to provide a pleasing continuity of outline. The totally enclosed series wound universal motor runs at 12,000 r.p.m. and is resiliently mounted in the die cast casing so as to reduce noise to a minimum. It is fitted with an oil retaining journal bearing at the top and a ball bearing at the spindle end. The armature is wound on a sleeve pressed on to the stainless steel mixing spindle. The mixer is automatically switched on when the stainless steel beaker is placed in position on a spring loaded stud, which operates a mercury tube switch. As this switch is sensitive to movement of the unit as a whole, a spring loaded isolating switch is fitted under the base so that if the mixer is tilted or raised off the counter the mercury switch becomes inoperative until it is put back again. This device is an important detail in the design which acts as a safeguard against the mixer's being inadvertently set in motion.

Fig. 38.—New drink mixer and beaker.

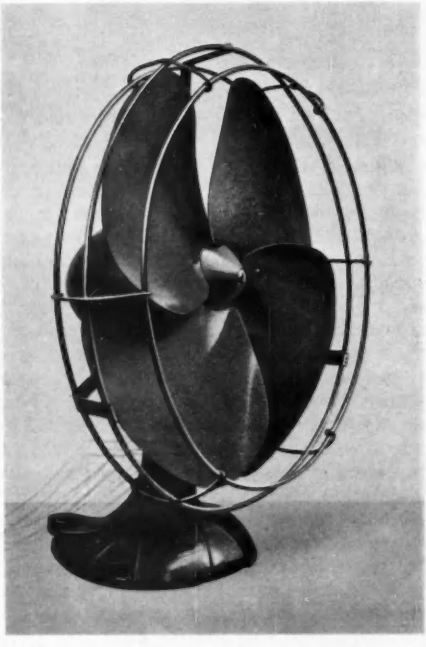


Fig. 37.—16 in. table or bracket type oscillating fan.

Insulation of Machines.

Considerably improved resistance to moisture and greater electric strength have been obtained with the use of a new oil-modified synthetic varnish which solidifies through polymerisation, whereas the oil-base varnish formerly used sets through evaporation of the solvent and oxidation. The new varnish is being brought into use for insulating the windings of all machines from the small fractional horsepower motor to the largest generators built. Lengthy tests in cold-wet atmospheres, and tropical cycle tests carried out in the laboratory, indicate that machines impregnated with the new varnish withstand such conditions many times longer than those impregnated with the oil varnish. It should be mentioned that the new varnish has very little effect on ordinary enamelled wire and none whatever on enamel of the polyvinyl acetal type such as Pygenam, a product of Pirelli-General Cables Works.

MECHANICAL HANDLING.

The Blending of Coal for Coking.

A comprehensive article on the iron ore preparation plant at the Corby Works of Stewarts and Lloyds Ltd., appeared in this Journal in July 1949, in which the Robins-Messiter system of bedding and blending iron ores was fully described and illustrated. It is

thus of considerable interest to record that an order has recently been placed for a Robins-Messiter blending system to be used in the preparation of coal for coking purposes.

As a matter of historical fact it may be noted that this system was originally used for blending copper ores and it was in this country that it was first employed with iron ores. However, it has long been recognised that the system could be adapted equally well to the blending of bulk materials other than ores and the present contract marks the first occasion on which it will be used for blending coals for coking.

It is confidently anticipated that this new application will be widely adopted both here and on the Continent. This will call for much specialised equipment for the actual blending operation and, in addition, a great amount of ancillary gear in the way of handling, crushing and screening plant.

While the blending of coal for coking purposes is nothing new, the importance of the present contract lies in the fact that the degree of intimacy of blend obtainable by other methods does not approach that afforded by the Robins-Messiter system.

The system also offers great advantages in capital cost, particularly where large quantities of coal must be stored. It enables great amounts to be kept in stock on the ground in a bedded condition, in readiness for reclamation in a fully mixed condition for use as required in the coke oven or other carbonising plant. Yet a further advantage is the extreme flexibility available for the various grades of coal needed for the required mixture. This enables the best possible use to be made of available supplies.

Fig. 39.—Chance coal washing plant at Cornelia Colliery, South Africa.

Coal Preparation Plants.

Orders for three coal preparation plants have been received from South Africa, and it is of interest to note that they will all be similar to plants of G.E.C. manufacture already in operation at the collieries concerned. One installation for Schoongezicht will have a capacity of 375 tons an hour and will be installed near the existing Chance equipment. It is to be fed from a new inclined shaft which is being driven into the coal seams at another part of the mine. Another installation is for Cornelia Colliery (fig. 39) where the first plant was installed four years ago to supply suitably treated coal to a new power station adjacent to the Vaal River. This station is now being extended and the additional coal needed will come from the plant now on order which will have a capacity of 220 tons an hour. Provision is being made on this plant for producing a small quantity of special coal for the domestic market. The third installation is for a new coal area which is being opened and which will be known as South

Rand. This plant also will have a capacity of 220 tons an hour and the output is intended to replace that from Springfield Colliery which at present supplies Klip power station and is gradually becoming exhausted. After the new installation has been put into commission the existing plant at Springfield will be transferred to another area and the increased output resulting from the operation of both plants will go partly to Klip station and partly to other new power stations which are under construction.

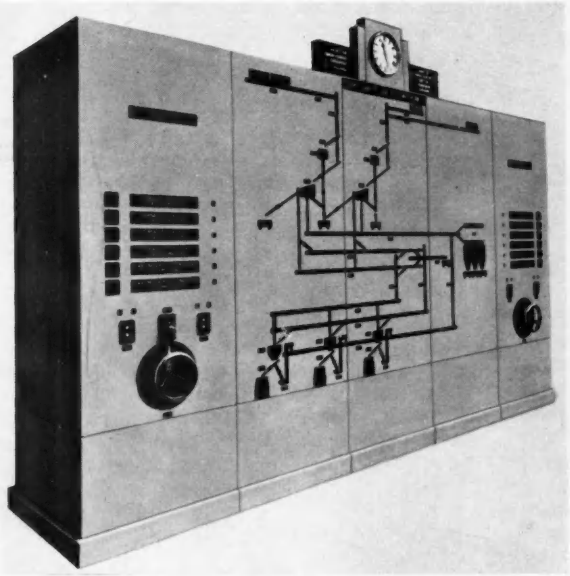


Fig. 40.—Mimic diagram for coke handling and screening plant for the Indian Iron and Steel Company.

Coke Handling Plant.

The automatic operation of industrial plant, especially where a continuous process is involved, is one that is ideally adapted to electrical control. A scheme of this nature for a coke handling and screening plant has been designed and built for the Indian Iron and Steel Co., for use with plant supplied by Simon Carves, Ltd.

The handling plant itself consists of a number of conveyors, crushers, screens and associated equipment which are controlled automatically in the correct sequence by means of control gear mounted on the control panel seen in fig. 40. The sequence of operation is as follows: the desired flow is set up by one or other of the control wheels on the side panels. It is then possible by means of one of the six auxiliary switches mounted above the controller to cause those parts of the diagram corresponding to the position of the control wheel to be illuminated. The operator can thus check that the arrangement he has chosen is, in fact, the one that he requires. If he finds that this is in order he presses the "start" button, and the various conveyors, crushers, and so forth, are started up automatically in the correct sequence.

TELECOMMUNICATIONS.

Radio Communications.

Multi-channel Links.

Increasing attention is being paid to the development of radio links as integral parts of telecommunications networks. This concerns not only such major achievements as the U.H.F. Television Radio-Relay Link, described elsewhere in this issue, but also the various aspects of V.H.F. multi-channel links now under development.

Tests are in progress to assess the performance of a 12/24 channel V.H.F., F.M. system extended to include radio repeater stations. Further experience has been gained from tests on the Wembley to Coventry link and on new production equipment, and improved techniques have been evolved to assist in operation and maintenance. To satisfy those demands which require an extra degree of reliability, provision has been made to add full stand-by equipment with facilities for automatic changeover in the event of failure. Fig. 41 shows the constructional features of the terminal station transmitter. The terminal station receiver and the relay station unit are of similar design.

Mobile Equipment.

To the range of mobile V.H.F. equipment an F.M. pack set has been added. This comprises a highly sensitive receiver and a transmitter of ½ watt output, operating on any single crystal-controlled frequency in the range 66 to 108 Mc/s.

The range of operation between two sets is normally about 2 to 3 miles, but considerably greater distances can be covered under favourable conditions of terrain.

The complete equipment is fitted into a canvas carrying case (fig. 42) with battery, telescopic aerial, and hand-set. The total weight is about 24 lbs. and the battery provides

approximately 10 hours' continuous operation on one charge.

Where a number of radio stations is used in a common frequency V.H.F. communication system, it is often desirable to have the facility of

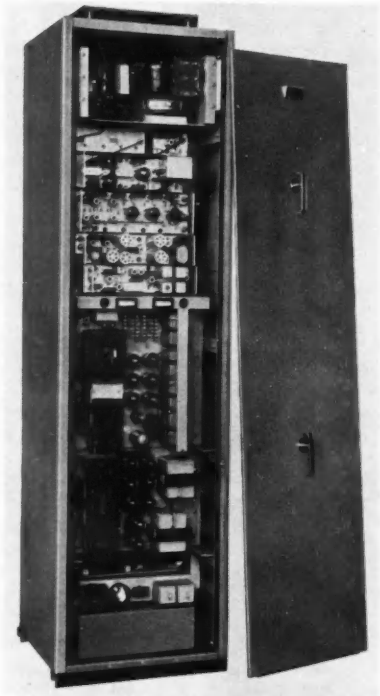


Fig. 41.—V.H.F.-F.M. multi-channel radio telephone equipment: terminal station transmitter.

calling an individual station without attracting the attention of the remainder.

Two selective calling systems providing this facility have been developed by the G.E.C., one known as the multi-tone system and the other as the impulse system. Either of these can be used with the standard A.M. or F.M. equipments without affecting the performance.

The multi-tone system utilises a number (up to 10) of audio frequency tones in the frequency range of 300 to 3,000 c/s. This system, in its simplest form, is limited to ten circuits, but by using two tones simultaneously or sequentially the number can be considerably increased.

The impulse system uses a desk telephone instrument fitted with a standard Post Office dial at the control station ; this interrupts the output from a single frequency modulating oscillator unit.

At the receiving end a " decoder " unit provides for one, two or three digit dialling as required and besides individual calling allows for " group " and " all-stations " calling. This is particularly useful in a police radio communication system when, say, numbers of cars in a certain area have to act quickly on instructions from the control station. Fig. 43 shows the complete equipment for the mobile end.

Piezoelectric Crystals.

Research on the preparation of synthetic crystals as substitutes for natural quartz has continued. Oscillator plates have been fabricated from quartz crystals grown in an autoclave from aqueous solution under a pressure of 1,000 atmospheres and a temperature of 360 degs. C.

Fig. 42.—V.H.F.-F.M. pack type transmitter/receiver in use.

The crystalline quality of synthetic quartz grown under optimum conditions is up to the standard of the best natural quartz ; in particular, B-cut synthetic quartz oscillator plates have been made which are comparable in all respects with natural quartz plates. In the investigation of substances other than quartz, filter crystals for use in multi-channel carrier telephony are being made

using ethylene diamine tartrate. These crystals are being grown in plant specially developed for this purpose.

Acoustics.

A new echo-free room for acoustic measurements has been constructed at Wembley. This contains 3,000 sound-absorbing " Fibreglass " wedges which project inwards about 3 ft. from the ceiling, walls and floor. A railway system with a turntable is fitted for the apparatus under test and a sound transparent floor consisting of a strong metal grid is provided for the operators. Fig. 44 shows the room in course of construction.

Fig. 44.—Echo-free room for acoustic measurements. The room is shown in the course of construction with part of the sound transparent floor in position, and a view of a " Fibreglass " wedge.

Telephone Equipment.

Four main developments of apparatus for automatic telephony have been carried out by the Telephone Works, Coventry.

The heavy-duty uniselector shown in fig. 45 has proved to have a life four times that of the present two coil standard. There is also an improved design of a light-duty uniselector incorporating an adjustable wiper assembly. Both types of uniselector have been standardised by the British Post Office.

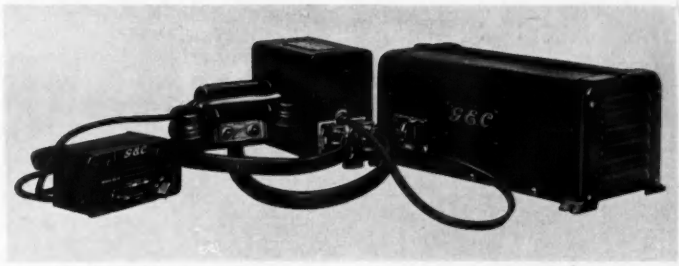


Fig. 43.—Selective calling equipment, mobile end. (*Left to right*) Indicator unit, controller, decoder unit, V.H.F.-F.M. transmitter/receiver B.R.T. 154.

The new two-motion selector offers many advantages over the present B.P.O. standard 2,000-type selector. It is easy to assemble, adjust and maintain and can perform all functions peculiar to the Strowger-type and 2,000-type selectors. It can be fitted in the same mounting cradles as the 2,000-type.

The new trigger-type dial offers advantages in simplicity, accuracy and reliability. It is interchangeable with the previous standard-type B.P.O. Dial Auto No. 10.

Rural automatic exchanges are being manufactured in increasing quantities for use at home and abroad, and complete installations of automatic and manual exchanges have been provided on several new and refitted passenger vessels.

In conjunction with the Admiralty, new fleet exchanges for naval vessels have also been developed. These exchanges are constructed on the unit principle, each unit having a capacity for 50 lines. The units can be multiplied to provide installations of up to 500 lines.

Traffic control equipments have been installed at many offices of British Railways. Of particular interest is the re-equipping of the busy goods area at Burntisland with a traffic control system employing " selective ringing ". Fig. 46 shows the traffic control desk.

A simplified form of " train describing " has been used on the Liverpool Street-Shenfield route (Eastern and North Eastern Regions) to meet the demands caused by electrification of the track.

Two important remote supervisory control systems have been manufactured and installed.

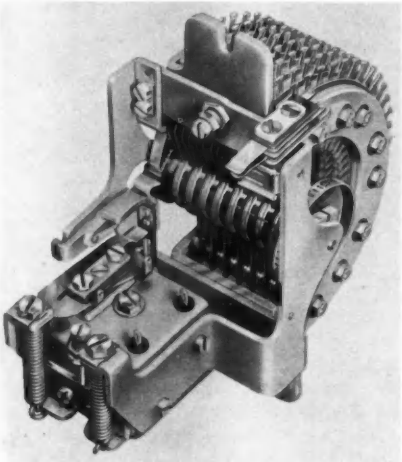


Fig. 45.—Heavy-duty uniselector.

The first, supplied to the Waitemata Electric Power Board, New Zealand, provides remote supervisory control of switchgear in a group of ten substations, with remote metering of busbar and feeder loads and intertripping between certain feeders. The second system, supplied to the London Transport Executive for their North-Eastern Extension, provides a maximum of sixty controls with indications at any one of the substations controlled. A feature of this equipment is the rapidity with which track supply switching can be carried out.

Television.

During the year two new television receivers have been developed and produced, a 9 in. tube model for television only, and a 14 in. tube model for television and radio reception. Both receivers are of the superheterodyne type, using intermediate frequencies of 13·5 Mc/s and 10 Mc/s for vision and sound respectively.

The 9 in. receiver in both table and console models, and the 14 in. combined model are suitable for use on either the London or Birmingham system.

Considerable economy has been achieved by the derivation of the cathode-ray tube E.H.T. voltage from the horizontal deflection circuit using a new type of miniature wired-in rectifier (U37). With this high frequency voltage source the capacitance between the inner graphite coating of the cathode-ray tube and an additional external coating is sufficient to act as the smoothing capacitor of the rectified supply. The voltage has been increased to 6·4 kV for the new cathode-ray tube which has an aluminium-backed screen.

The receiver has a sensitivity of 100 microvolts for full output on vision and 10 microvolts on sound. A table model of this set (BT1091) is shown in fig. 47. The three controls: focus, brightness and sound volume (with on/off switch), required for normal operation, are located on the front of the set.

The 14 in. tube receiver (BT9144), shown in fig. 48, is made in console form. This model also is fitted with a cathode-ray tube of the new type. As in the case of the 9 in. tube receiver the set is designed to provide sufficient sensitivity to operate anywhere within the service area of the transmitter.

Valves and Cathode-Ray Tubes.

Crystal Valves.

Considerable advances have been made since the war in the development of both silicon and germanium point contact rectifiers.

Fig. 46.—Burntisland traffic-control desk.

Experience with centimetre wave radar equipment showed that damage was done to the earlier capsule type silicon crystal (fig. 49a) when it was inadvertently exposed to the radar beam. A new type silicon mixer crystal has now been developed, in which the rectifying element is shielded from external fields by an outer metal tube (fig. 49b). New techniques have been developed for the manufacture of this crystal, which have resulted in a much more uniform product and improved sensitivity.

The germanium rectifier crystal is now in production, but work is still continuing in an effort to improve the characteristics, especially the voltage handling capability.

It has been shown by the Bell Telephone Laboratory, that if two cat's-whiskers, spaced about 0·004 in. apart, are arranged to make contact on a wafer of germanium, the other face of which has a soldered contact, then the current

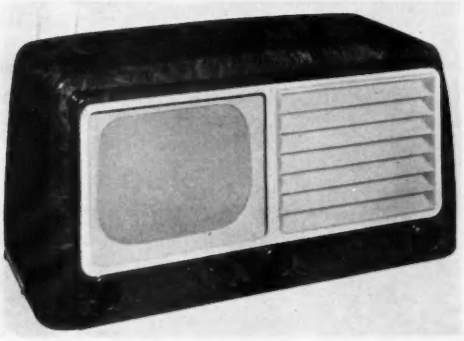


Fig. 47.—9 in. tube television receiver table model, type BT1091.

to one whisker can be controlled by the voltage on the other. This device is called the "Transistor". The main difficulty was to obtain a satisfactory mechanical design which could be manufactured at low cost.

Fig. 49c shows an experimental design which overcomes many of the difficulties. It consists of two metal plates in place of two whiskers, supported by an insulator and spaced about 0·004 in. apart by jig assembly. The germanium is soldered on to a metal rod and ground to a cone, the apex of the germanium cone being arranged to bridge the gap between the plates. Two point contacts on to the germanium are thus obtained, in which the spacing is accurately controlled.

Units have been made which operate with about 20 volts H.T. and which have a mutual conductance in excess of 10 mA/V at a current of about 2 mA. The properties of these crystals are very similar to those of thermionic triodes; they can be used as oscillators, amplifiers and cathode followers at frequencies up to about 10 M/cs.

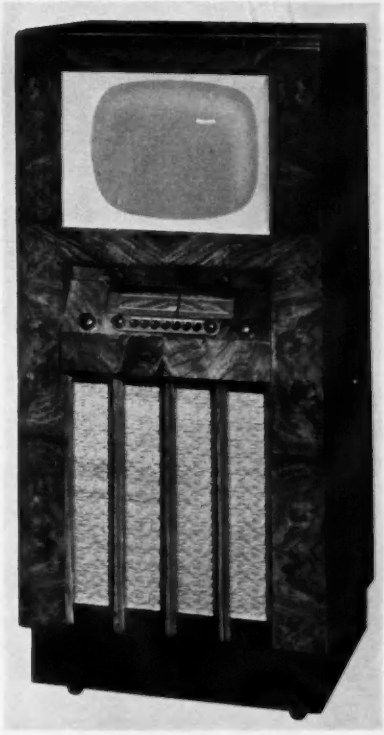


Fig. 48.—14 in. tube television receiver, type BT9144.

Cathode Ray Tubes.

During the past year a great step forward has been taken in the control of the ion burn which has been associated universally with high efficiency cathode-ray tubes for television. All magnetic television tubes now in production have fluorescent screens which are backed with a layer of aluminium. The thickness of the aluminium film is adjusted so that ions are stopped but the electrons are able to penetrate and excite the screen in the normal way. Close control of thickness has accomplished protection from ion burn without the loss of brightness. In addition to protection from ion burn, the aluminium-backed screen gives a picture with much better contrast under normal conditions of use since, being opaque to light, the aluminium

stops light from " white " areas of the screen falling on " black " areas.

Deflection defocusing of television tubes has also been improved by redesign of the gun. This has been done without any increase in tube length.

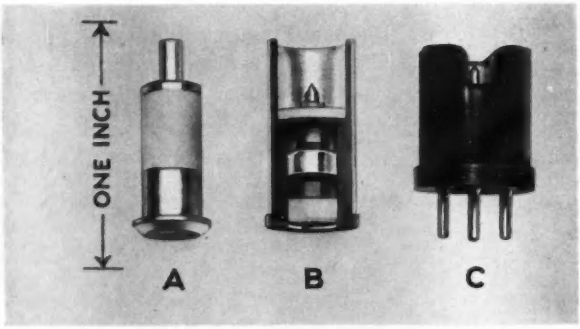


Fig. 49.—Crystal valves : (*a*) Early capsule type diode ; (*b*) Screened diode ; (*c*) Experimental crystal triode.

A 12 in. television tube has been developed and will shortly be in production.

Numerous types of special cathode-ray tubes have been developed at the Laboratories. They include storage tubes and electronic switches for digital computing applications.

The storage tube (Ref. 1601 AXA) was developed in conjunction with Manchester University and is capable of storing approximately 2,048 units. The electronic switch tube (2290 BCA) is a 40-contact switch designed for routing signals in computers and consists of a row of 40 buckets supported across the diameter of a 9 in. diameter cathode-ray tube. Cross talk between adjacent contacts is less than 0·1 per cent ; a beam current of 20 μA is available and this may be modulated in the usual way.

Valve Life-testing Equipment.

Substantial progress has been made during the year in the re-equipping of the valve life-test department at the Research Laboratories. An important element in the design of life-test equipment is its ability to meet the widely different requirements of various types of valves. Only a small proportion of the total number of valve types marketed by the Company is produced by the Valve Works at one time. Life-test facilities must therefore be capable of easy conversion from one type of valve to another if equipment is not to remain idle. This requirement has governed the design of the new life-test equipment, and a small range of standardised parts is now used to make any type of panel required for regular life-testing. The ease with which non-standard tests can be run has confirmed the fundamental features of the design.

A section of the new equipment is shown in fig. 50. The valves on test occupy the main centre area of the rack with the switching and fault indicator panels above. At the top of the rack are the busbars and cable ducts. High and low tension supply units are housed in the two panels at the bottom of the rack. The racks are double sided and are used for life-testing all types of receiving valves, electrometer valves and crystal rectifiers.

A valve panel with covers removed is shown in fig. 51. Running conditions are checked by means of a portable instrument trolley, and an automatic checking and fault-locating unit has been developed, to eliminate the daily manual checking which has hitherto been necessary.

X-RAY EQUIPMENT.

In designing an X-ray couch or similar item

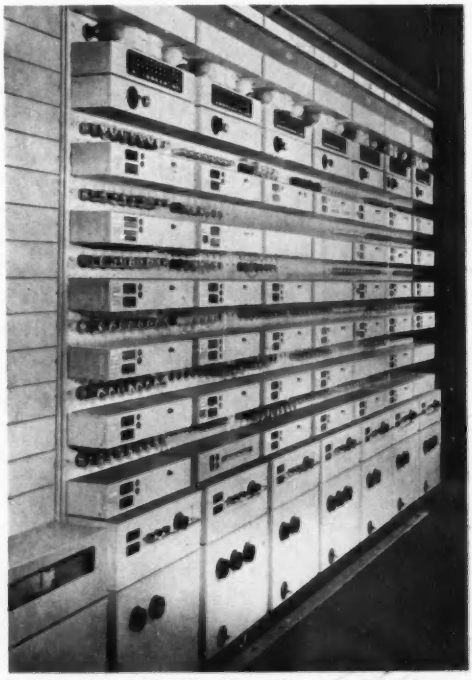


Fig. 50.—A rack of valve life-testing equipment installed at the Research Laboratories.

of equipment, full consideration must be given to the many different radiographic procedures for which it will be employed, and this clearly entails a very wide knowledge of the subject which can be gained only by long experience.

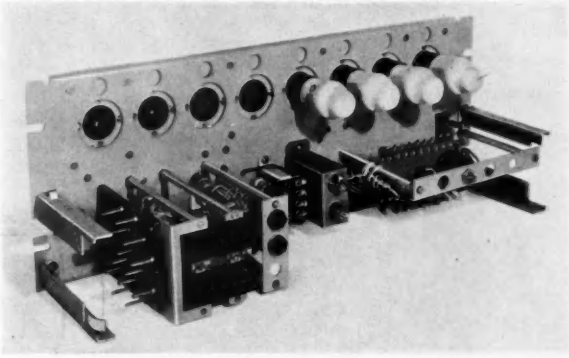


Fig. 51.—Valve life-testing panel with dust cover removed.

The "Autonome III" motor-driven couch, which is illustrated in fig. 52, is a good example of modern engineering principles applied to practical radiographic needs and it embodies in its design several new mechanical and electrical features which make for improved radiographic efficiency and greater comfort for the patient. In addition it is considerably more convenient for the operator to use.

The supporting pedestals and all driving mechanisms are concealed behind side panels which are flush with the upper edge of the couch top. This gives a neat appearance and allows the operator to stand close to the couch when he is screening the patient.

A magnetic brake arrests the movement at any position without jarring when coming to rest. The time taken to tilt from the vertical to horizontal position is 15 seconds, the movement being smooth and practically silent. Limit switches preclude the possibility of over-running, and electro-mechanical interlocks are fitted to prevent accidental damage to the X-ray tube or couch mechanism.

A feature of the couch is its relatively low weight, due in part to the extensive use of light alloys, but also to a reduction in the amount of counterweighting employed.

The Potter-Bucky diaphragm (a device for absorbing secondary radiation) is so arranged that it is always free of the path of radiation when the undercouch tube is in use. The diaphragm is arranged for electrical release in conjunction with the control of the X-ray generator.

The twin column tube stand is very robust and capable of supporting a rotating anode X-ray tube without vibration. A novel and important feature is a new type of tube clamp which makes it possible to rotate the X-ray tube about the centre of the tube focus.

The couch is supplied complete with a full range of radiographic accessories including the serial cassette changer. This is a device for use during examination of the stomach region. It enables a series of radiographs to be made in rapid succession with or without an opportunity for the radiologist to carry out a visual screen examination between exposures. As each portion of the cassette is brought into position, the X-ray exposure is made automatically, the tube loadings being changed from screening to radiographic values without any further action by the operator.

A number of "Autonome III" couches will be supplied to British hospitals for use in conjunction with Watson "Roentgen IV" generators and Machlett X-ray tubes.

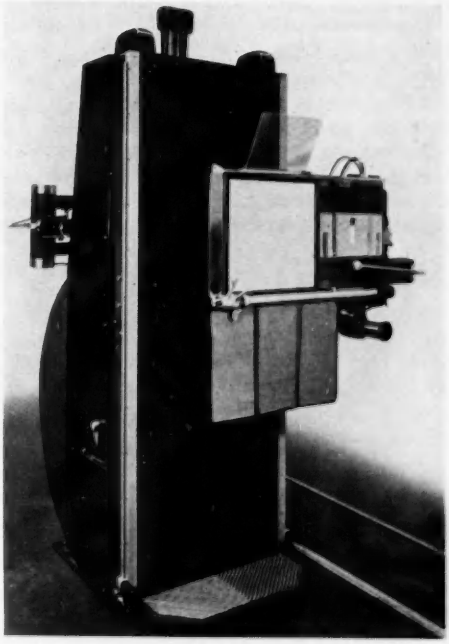


Fig. 52.—The "Autonome III" X-ray couch.

MEASURING INSTRUMENTS

The manufacture of a new product often involves the design of special measuring and testing equipment. During the past year the commencement of manufacture of the $\frac{3}{8}$ in. diameter telephone type coaxial cable at the Pirelli-General Works at Eastleigh has required the development of special measuring equipment by the Research Laboratories.

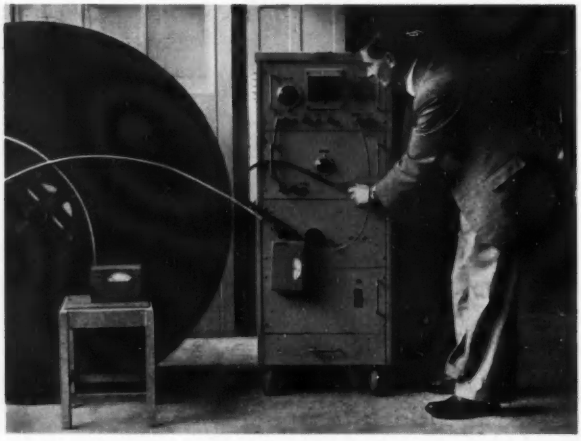


Fig. 53.—Pulse-testing equipment for measurement of electrical characteristics of telephone cables.

A pulse-testing equipment has been constructed for measurements on cables up to 1,000 metres in length. With this equipment both the position and magnitude of any irregularity along the cable can be determined. By using a pulse width of only 1/30th microsecond, it is possible to detect an irregularity in the cable equivalent to an impedance change of 0·05 ohms at a distance from the input of 1,000 metres. A view of the set in use is given in fig. 53.

The impedance of any cable varies with frequency, being asymptotic to a resistive value with increasing frequency. Special networks have been constructed which follow the theoretical impedance-frequency curve of the telephone type coaxial cable within 0·03 ohms over the frequency range 0·8 Mc/s to 7 Mc/s. The asymptotic value of the curve may be varied over a range of 1 ohm. These networks, one of which is shown in fig. 54, can be used as a termination for a length of cable or as an impedance standard for measurements of the impedance deviations of a cable.

Development work has continued on other forms of measuring equipment, and in particular a high frequency bridge covering the range 20 to 100 Mc/s has been completed. This bridge (fig. 55) is for measurements on aerials, cables, and similar impedances. The bridge uses continuously variable ratio arms in the form of a semi-circular inductance loop with a movable tapping point.

The range of parallel resistance of the unknown can be from one-third to three times the D.C. value of a standard resistor, the scale being approximately logarithmic and independent of frequency. The standard resistor

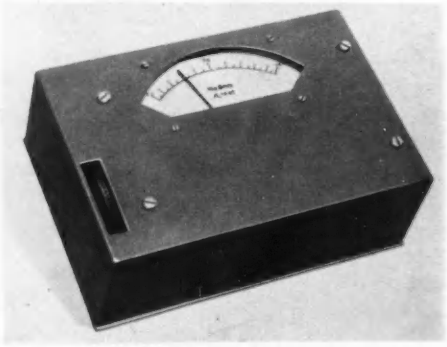


Fig. 54.—Network unit for impedance tests on telephone coaxial cables.

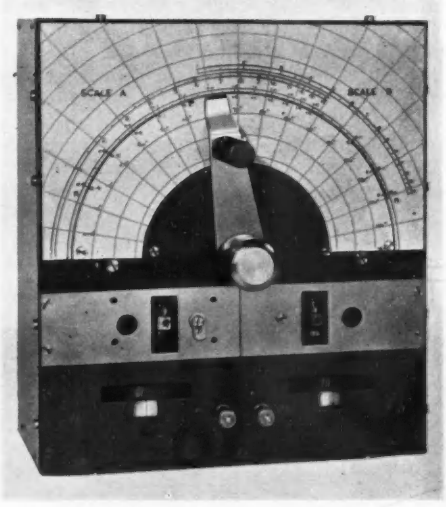


Fig. 55.—Bridge for impedance measurements on aerials, cables, and so forth, at V.H.F.

used can have any value in the range of about 30 to 100 ohms. The parallel reactance of the unknown can lie in a range equivalent to about ± 20 p.F.

One method of measuring the voltage gain of a system uses a signal generator to supply the input and a valve voltmeter to indicate the output of the system. The voltage gain can then be measured in terms of the generator attenuator. If this method is to be extended to systems which have a loss of voltage amplitude through them, then the output indicator must be capable of reading somewhat less than the maximum output of the generator ; which in the frequency range of 40-100 Mc/s is only 100 mV. As the majority of valve voltmeters do not give practically useful readings for voltages as low as 100 mV, it becomes necessary to develop an indicator instrument of greater sensitivity, of the order of 3 mV of modulated carrier signal for full scale reading.

Fig. 56.—Indicator instrument for measurement of output of signal generators. The scale is in inches.

The instrument, illustrated in fig. 56, uses a germanium crystal detector at the input followed by a stabilised low frequency amplifier of controllable gain. While the unit is primarily intended as a stable indicator, it can be calibrated as a valve voltmeter at the lower gain settings where the scale is sufficiently linear.

An instrument designed in the Laboratories for a particular requirement may, later, find much wider use. This is the case with the instrument described below. It was initially developed for detecting changes of temperature of the order of 1 deg. C. in molten glass being fed to automatic machines.

The instrument is essentially a universal photoelectric photometer in which the housing for the photometer unit contains an optical system for focusing the radiation from a hot body on the cathode of the photoelectric cell. For temperatures above 900 degs. C. a photometer unit containing a potassium cell, type KMV6, is used. This is replaced by a caesium cell, type CMV6, for temperatures in the range 700-900 degs. C.

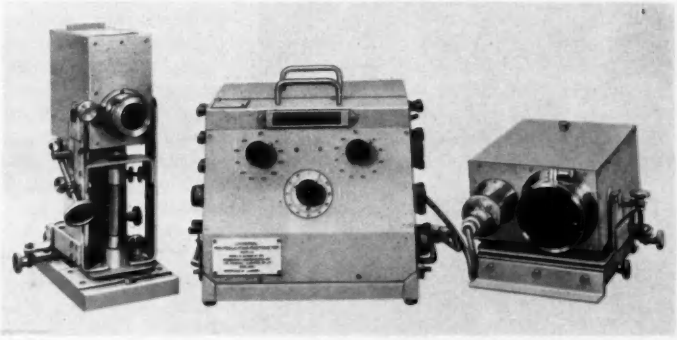


Fig. 57.—Photometer instrument for temperature measurements in molten glass (right).

In fig. 57, the tele-receptor, housing the photometer unit, is shown on the right, and the universal photoelectric photometer in the centre. The pyrometer standardising lamp is shown on the left.

LAMPS AND ILLUMINATION.

Discharge Lamps and their Application.

Among the many problems which arise out of the widespread use of fluorescent lamps those of colour rendering and colour appearance are perhaps of most importance at the present time. During the past twelve months much intensive work has been devoted to the control and measurement of these characteristics.

During the year a new cold white colour, known as " Colour Matching ", was added to the existing range of white lamps and is available in the 4 ft. 40 watt and 5 ft. 80 watt ratings ; the commercial requirements for other ratings are being examined. This colour is similar to that of the Osram cold cathode colour matching unit described in an earlier review of Progress,[1] and is already finding application for general lighting where light similar to that of an overcast north sky is required.

For decorative and recreational lighting, particularly where it is desired that foodstuffs should look normal and the complexion attractive, tungsten filament lamps with tinted fittings are generally used. The problem of reproducing an acceptable colour of this type by means of a fluorescent lamp was not easy, but after considerable research a colour was evolved which appeared to meet the need. The reactions to this colour of many hundreds of observers were noted, and later extensive trials were made in restaurants and private houses. These proved so successful that the new colour—the Osram " Mellow " fluorescent lamp—was adopted and is now on the market. The 5 ft. 80 watt size is available and other sizes will follow.

A noteworthy advance during the year has been the development of dimming control gear for fluorescent lamps. This is a logical extension of the dimming technique used by the G.E.C. for cold cathode fluorescent lamps described in a pre-war issue of

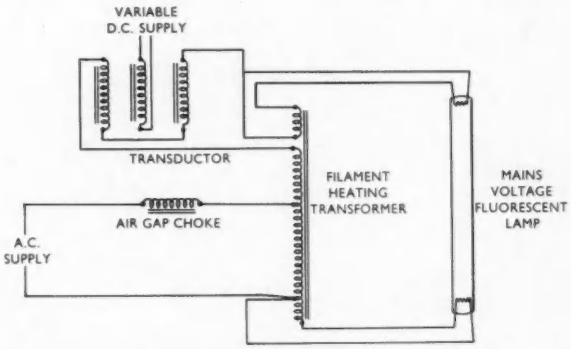


Fig. 58.—Circuit for dimming mains voltage fluorescent lamp, showing transductor for controlling lamp current, transformer for supplying supplementary filament heating current, and air gap choke for compensating supplementary filament heating current.

Fig. 59.—The Quarter Deck at the Royal Naval College, Dartmouth. The lanterns are equipped with Osram 3 ft. and 2 ft. fluorescent lamps while auxiliary fittings at the sides are fitted with filament lamps.

[1] " Electrical Progress and Development." *G.E.C. Journal*, Vol. XV, No. 1, p. 32. February, 1948.

purchase tax these have now largely given place to types which are more decorative in appearance. It is only very recently, however, that there has been a tendency to design fittings of more traditional style for fluorescent lamps. This trend has been facilitated by the availability of the shorter lamps.

Typical examples are the bracket and pendant lantern fitting used in the Quarter Deck at the Royal Naval College, Dartmouth (fig. 59). These follow the lines of the poop lanterns used in Nelson's time (fig. 60). A much more recent style is seen in the central pendant fitting in the entrance hall of the Institution of Electrical Engineers, which accommodates twenty Osram 2 ft. 20 watt fluorescent lamps (fig. 61). These examples illustrate the effectiveness of traditional lantern designs for fluorescent lamps. In the lecture theatre of the Institution special grids of Osram cold cathode fluorescent tubing have been used to good effect in the cornice and ceiling lay-lights, which, incidentally, were

Fig. 60.—Detailed view of the bracket lantern design, Royal Naval College.

this Journal.[1] The methods of control of light output by means of D.C. saturable reactors used for the high-voltage lamps have been extended to mains voltage types. Problems peculiar to the latter lamps, arising out of the limited voltage permitted and the need for maintaining the hot cathodes close to their optimum temperature for all discharge currents, have been solved.

Dimming equipment has been designed and is in limited production for Osram 5 ft. 80 watt fluorescent lamps (fig. 58). Dimming gear for other ratings, including the Osram 8 ft. 125 watt lamps has also been investigated and will be made available when the commercial requirements have been fully explored.

During the war years the use of Osram fluorescent lamps was mainly in association with fittings of functional design. Despite the handicap of

[1] "Fluorescent Tube Lighting." *G.E.C. Journal*, Vol. IX, No. 3, p. 163, August, 1938.

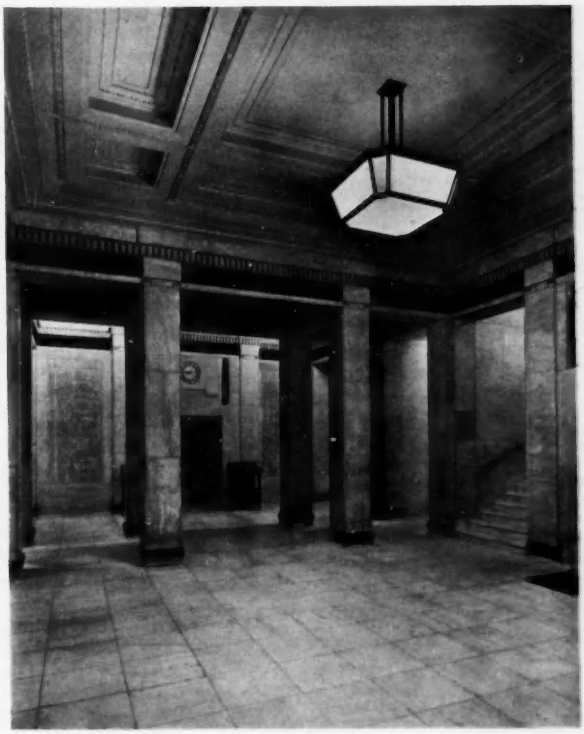


Fig. 61.—The Entrance Hall of the Institution of Electrical Engineers. The pendant fitting is the sole source of light in the front portion, the rear and wings are lighted from the fluorescent lamps in fittings concealed behind the beams.

designed and made by the G.E.C. some twenty years ago for filament lamps. All these tubes are fitted with the dimming equipment mentioned above.

During the year, fluorescent fittings and control gear of relatively very light construction have been developed for aircraft (fig. 62). Several passenger machines have now been equipped and the illumination provided is considerably greater than that given by filament lamps taking the same load. Power is obtained from the normal 24 volt D.C. supply through an inverter generating 110 volts A.C. at 400 cycles. The advantages of the higher frequency supply are that the control gear for the lamp can be made much smaller and lighter and starting can be accomplished without the use of a starting switch.

Considerable thought has been given to the production of fluorescent fittings and control gear of moderate cost for use in the home. One method of doing this which necessarily involves some sacrifice in overall luminous efficiency is to replace the usual choke by a filament lamp ballast. The efficiency and colour rendering of the combination is somewhat improved if the light from the filament lamp ballast is utilised and considerable progress has been made in the design of suitable fittings to enable this to be done.

The increasing use of " Perspex " for decorative fluorescent lighting fittings was mentioned in the review of Progress in this Journal in January, 1949. The past year has seen the further use of this material for optical control particularly in street-lighting fittings. Worthy of mention in this connection is a main road lantern using three Osram 80 watt 5 ft. lamps. The optical system of this fitting, shown in fig. 63, is a large " Perspex " trough with refractor panels in the inner surface. The ease of maintenance and low weight are important features.

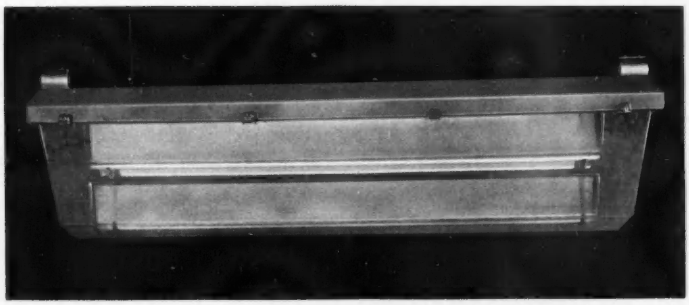


Fig. 63.—Street-lighting lantern housing three Osram 5 ft. 80 watt lamps, and fitted with " Perspex " refractors.

Interesting and attractive lanterns housing vertically burning fluorescent lamps have been designed. These lanterns emit about half their light above the horizontal and are intended for the lighting of city centres, ornamental gardens and places where there are buildings of architectural merit. One of these lanterns accommodating four Osram 80 watt 5 ft. lamps is shown in fig. 64. While this type of lantern is not intended primarily for normal street-lighting, it has been welcomed where appearance is of first importance.

Other new lanterns include a totally enclosed type with a " Perspex " optical system for 85 and 140 watt Osram sodium lamps (fig. 65) and with a glass optical system for horizontal burning 250 and 400 watt Osram high pressure mercury vapour lamps. The latter is fitted with a magnetic deflector so that high efficiency lamps may be used (fig. 66). Both lanterns have smooth outer surfaces for easy cleaning.

Fig. 62.—The interior of a York aircraft of British South American Airways equipped with fluorescent lighting. The passenger saloon contains 14 Osram 2 ft. 20 watt fluorescent lamps arranged to give substantially indirect lighting.

An interesting demonstration street-lighting installation on the Hatfield By-Pass (fig. 67) makes use of the " blown cut-off " lantern with Osram 400 watt HPMV lamps for the lighting of double carriageway roads. The lanterns are placed in a single row on the central reservation, the spread of light being sufficient to cover both tracks.

In studio lighting the flexibility in performance of the now well-known Osram 2½ kW mercury-cadmium " Compact " floodlight has been greatly improved by the use of remote control gear which enables the arc to be struck and the floodlight brought into use from any reasonable distance. Control is effected through a length of light gauge three-core cable which connects the fitting to a small hand set in which are mounted starting and shutter control switches (fig. 68). It is possible to operate a maximum of six fittings simultaneously from one hand set at a central point by linking the fittings through further lengths of small gauge cable. The spotlight version of this equipment is now in production and gives a performance comparable with a 5 kW incandescent filament lamp unit.

Work on HPMV lamps has resulted in a new version of the Osram 1 kW quartz lamp to which reference was made last year. This lamp is of the same family as the well-known Osram 80 watt and 125 watt quartz lamps but is designed for operation on 400-450 volts A.C. supplies (fig. 69). It operates vertically with a narrow discharge column about 5 ins. long, and the voltage between the lamp terminals is about

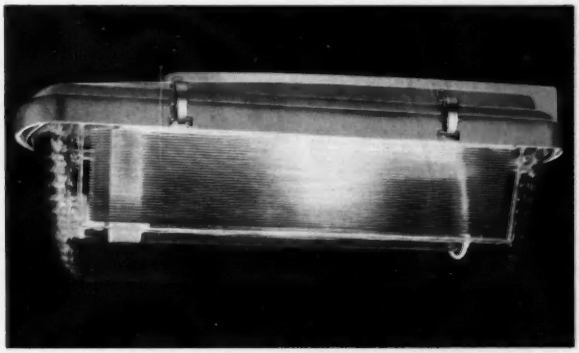


Fig. 65.—Totally enclosed street-lighting lantern for sodium lamps, employing an optical system of " Perspex ".

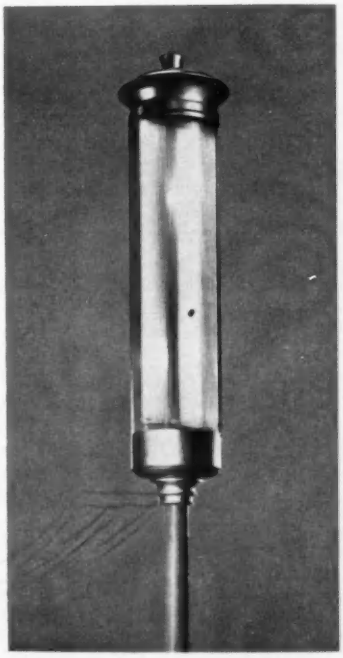


Fig. 64.—Vertical lantern housing four Osram 5 ft. 80 watt lamps for lighting city centres, ornamental gardens and similar locations.

Fig. 66.—Totally enclosed street-lighting lantern for horizontally burning HPMV lamps, opened to show the magnetic deflector and the lamp attached to the door.

300. The light output is more than that from three 400 watt HPMV lamps combined, and the useful life runs into thousands of hours. It should find particular application for high bay lighting where a large luminous output per fitting is important.

A new version of another lamp, the Osram 3 kW HPMV lamp for photo-printing, has also been developed in which the envelope is of quartz. This lamp has the advantage of giving about 50 per cent more long wave ultra-violet radiation than its glass counterpart, which is of first importance in photo-chemical processes. It is also less affected by ambient conditions than the glass lamp. A hard glass outer envelope is provided which effectively filters out harmful short wave ultra-violet radiation without reducing appreciably useful radiation from the quartz inner. This quartz lamp has approximately the same dimensions as the glass lamp.

Based on theoretical studies of the requirements of aviation lighting at the Research Laboratories, the Royal Aircraft Establishment, Farnborough, and elsewhere, many improvements in the design of existing equipment have been made and new equipment put into production. For example, the performance of the high intensity flush-mounted runway light has been improved, and in the latest design it is possible to adjust the direction of the beam of light both in elevation and in azimuth without opening the fitting. In certain conditions, as on airfields which are often snow covered, it is desirable to elevate the runway light some two or three feet above the ground on columns, and such a light has now been designed. Elevated lights must, of course, be placed well to the sides of the runway, and the light distribution is therefore somewhat different from that of the flush-mounted light. In particular, a wider spread of light in azimuth is necessary, calling for a greater light output. The relatively large fitting used for an elevated light makes this possible.

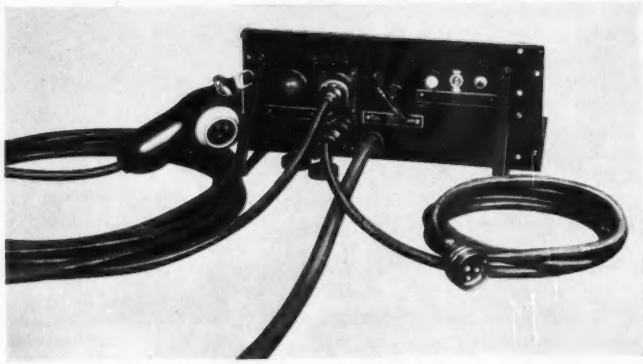


Fig. 68.—Control panel of remote controlled " Compact " floodlight with the hand set and interconnecting cable attached.

Fig. 67.—Installation on the Hatfield By-Pass using a single row of " blown cut-off " lanterns with 400 watt HPMV lamps for lighting the double carriageway.

For use in the Calvert approach system an approach light using a 140 watt sodium lamp is now in production ; the lamp is mounted horizontally in a high-purity aluminium reflector (fig. 70).

A small rotating beacon, shown in fig. 71, is available for indicating airfield positions where very high candle power is not essential, as for helicopter landings. Provision is made for remote control, and colour filters may be fitted to any of the four lenses to give a wide range of characteristics. Problems associated with the much larger aerodrome identification beacons

employing cold cathode fluorescent and neon tubes are being studied. In particular the relatively high rate of flashing now required for these beacons has made it more difficult to control the flashing by the contactor arrangements used formerly, and a new system of control using a gas-filled relay is giving promising results.

Lamp research and design must inevitably be closely associated with the study of glass. Two recent glass developments which are of the greatest interest in the lamp field may be mentioned. Recently a range of low melting point glasses has been produced which are used to join the normal types of soda and lead glasses together in a manner analogous to the use of solders in joining metals. These glass solders enable joints to be made at temperatures between 450 degs. C. and 500 degs. C. when no distortion of the work pieces occur. Investigations of the effects of the composition of glass on its ultra-violet transmission has resulted in glass having a transmission for radiation of 2537Å comparable with that of quartz. Such glasses are of great value for the production of powerful short-wave ultra-violet sources.

In the field of photometry and colorimetry there is a constant urge for higher accuracy and ease of operation. The Physical Eye Colorimeter and Spectro-Photometer developed at the Laboratories and referred to in the review of Progress in this Journal, January, 1949, has met a long-felt need, and an improved model, shown in fig. 72, is now in small scale production.

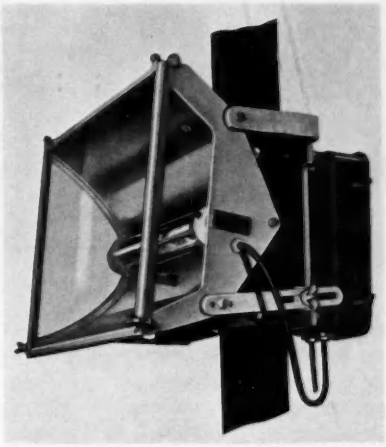


Fig. 70.—Sodium approach light as used in the Calvert Horizon Bar approach system.

The experience gained in this country using instruments of this type has enabled provisional agreement to be reached by the International Commission of Illumination on methods of measuring and specifying colour and colour-rendering properties of illuminants and particularly of fluorescent lamps.

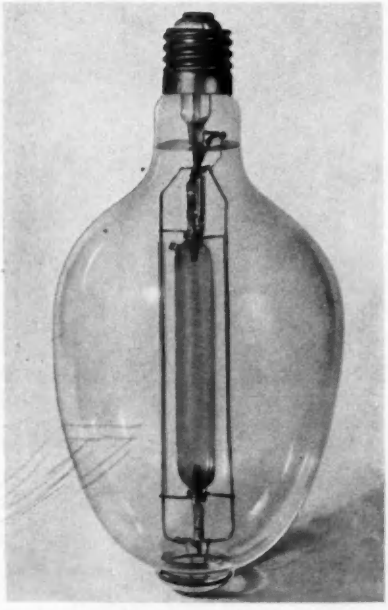


Fig. 69.—The new version of the 1 kW quartz lamp in an isothermal outer jacket.

Fig. 71.—Small rotating airport beacon for helicopter service.

Among the types of lamps made for special purposes during the past year may be mentioned a range of high intensity flash discharge lamps of small source size designed to give an extremely

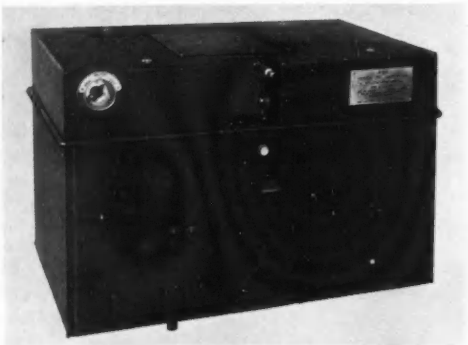


Fig. 72.—The G.E.C. Physical Eye Colorimeter and Spectro-Photometer.

bright pulse of highly actinic light. These lamps are proving of great value where it is necessary to produce a narrow beam of light having a small divergence, such as in Wilson cloud chamber photography. A typical example from the range is shown in fig. 73 which has arc dimensions of 15 mm. by 4 mm. diameter, and can dissipate up to 2,000 watt-secs. per flash with a duration of 1 millisecond. Due to the high instantaneous arc loading the peak brightness of the flash is considerably greater than that of the sun. The lamps operate from the usual condenser circuit at a voltage of 2,000 volts, and are triggered by applying a high frequency pulse to an external trigger wire. In the "Photoflash" type of high power flash source, considerable improvements in performance have been achieved by the use of finely chopped aluminium foil as the combustible material. One only of a number of proposed ratings is available at the moment (fig. 74) which gives a powerful flash of light of some 70,000 lumens/seconds with a peak emission of about 4 by 10^6 lumens. This method of construction ensures much greater uniformity of the time intervals between the closing of the firing circuit, the start of the flash and the maximum of the light output.

In the category of special lamps there are new types of Laboratory discharge lamps which employ an isotope of mercury or krypton in their fillings. These are intended chiefly for interferometric work where the use of the extremely narrow lines in the emission spectra of the monoisotopic metal-vapour or rare gas gives greatly improved definition in the interference patterns.

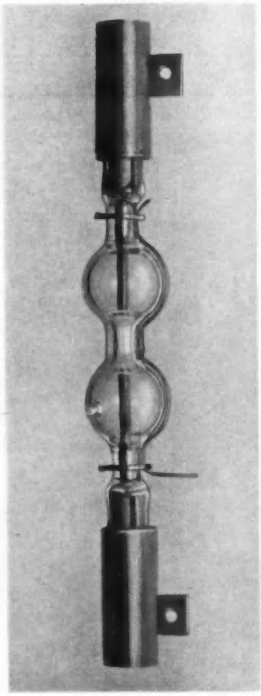


Fig. 73.—Quartz high brightness flash tube for Wilson cloud chamber photography.

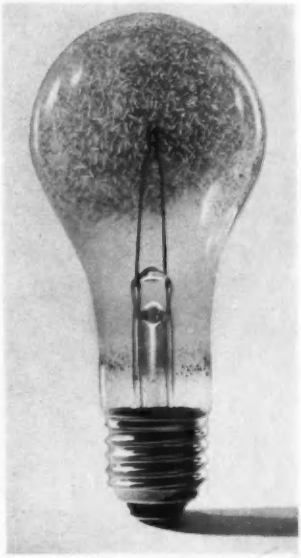


Fig. 74.—"Photoflash" bulb using finely shredded aluminium foil as the combustible material.

INDUSTRIAL AND PROCESS HEATING.

Two new single valve 2 kW generators (fig. 75) have been added to the range of valve oscillator high frequency heating equipment. The dielectric heating model is intended chiefly

Fig. 75.—2 kW 20 Mc/s dielectric heating set for operation on 3-phase, 360-440 volt, 50 cycle A.C. supplies.

for preheating thermo-setting plastic moulding materials, but can also be used for heating small quantities of rubber and similar materials. The built-in oven with counter-balanced lid encloses a pair of 10 in. by 8 in. electrodes which are adjustable from outside.

The eddy current heating set is suitable for such processes as brazing, soldering, through-hardening and the surface hardening of small parts. A load meter is provided and an adjusting knob on the front panel enables a wide range of loads to be matched. The heating coil is mounted at the side of the cabinet.

One of the difficulties with H.F. heating is that variations in the nature of the load being heated produce variable amounts of electrical mis-match in the circuit. To counteract this an on-load variable matching unit and an oven have been developed as auxiliary equipment for the 5 kW dielectric heating set. The patented matching unit (fig. 76) incorporates a coil made of $\frac{1}{2}$ in. copper tube which is rotated by the control knob and which makes contact on its outer surface with a wheel which is free to rotate and to travel along a fixed spindle arranged parallel to the axis of the coil. The inductance will carry at least 35 amps. without forced cooling. Single meters are used to indicate the load both on the matching unit and on the oven. The oven contains a pair of 24 in. by 18 in. plate electrodes whose distance apart may be varied from zero up to 6 ins. by means of an external adjusting knob. An off-load variable matching inductance is included in the electrode circuit and may be preset before switching on. Fine control is obtainable by adjusting the electrode spacing.

H.F. heating probably shows the greatest advantage when associated with special purpose machines and the heating units have been designed for the greatest efficiency in relation to the work to be treated. Several new items of such work handling equipment have been developed. One for rocker hardening operates in conjunction with a 5 kW generator. The rockers are loaded manually and are heated,

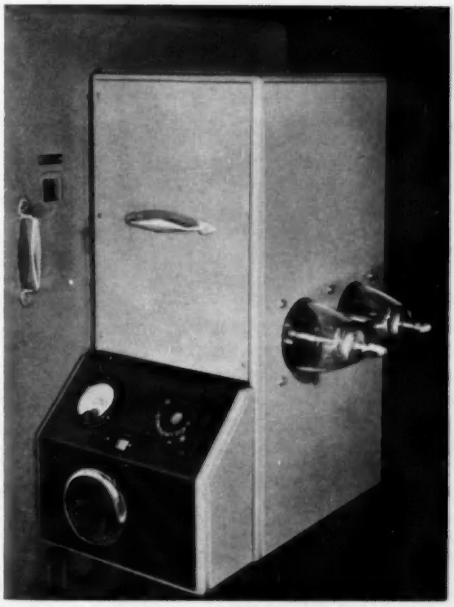


Fig. 76.—On-load variable matching unit for 5 kW dielectric heating set.

quenched and unloaded automatically with the aid of a pneumatically operated indexing mechanism which is controlled electrically by a process timer. A machine for soldering or brazing is illustrated in fig. 77. The components to be treated are assembled in jigs and

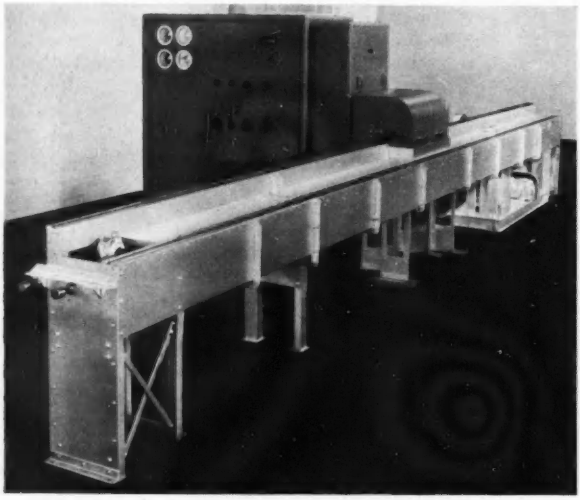


Fig. 77.—5 kW high frequency heating set and conveyor for soldering and brazing.

are carried past the heating coil on a variable speed conveyor. The small induction furnace shown in fig. 78 works in conjunction with a 5 kW generator and is intended for heating charges weighing a few pounds to temperatures of about 2,000 degs. C. Alternative graphite and ceramic crucibles are available and a ram mechanism is included so that the crucible may be withdrawn easily from the coil assembly.

Several large furnace and radiant heating installations have been completed. The furnaces are used chiefly for metallurgical processes and pottery firing (fig. 79) and many of them are now of standard patterns which follow well-established designs.

In the case of the lower temperature radiant heating, development has been in the direction of securing greater flexibility. When this process was introduced each plant was usually designed to handle only a limited range of articles. Now, however, greater flexibility is achieved by careful adjustment of the heating intensity and of the arrangement of the painted articles on the conveyor hangers. Thus a wide range of shapes and sizes may be handled simultaneously in a single plant. For example all the component parts of a series of kitchen sink units and cabinets, including small light gauge panels, drawers and complete side and front assemblies, are handled simultaneously in one reflector lamp plant (fig. 80).

Another installation which handles varied components is shown in fig. 81. It is used for processing aluminium body sections of cars and includes two internal reflector lamp plants. The first is used for drying the components after the rinsing operation which follows a spray pre-treatment process and the second for stoving the paint coat which is subsequently applied. All processes are carried out automatically on the same conveyor and, in order to permit the line to be stopped and restarted at will without affecting the finish, some special control equipment has been provided. This incorporates a series of separately adjustable time delay switches, one on each of the eight sections of the stoving plant and others on the preheating plant and conveyor. When the line is started up after having been shut down for a period, the centre

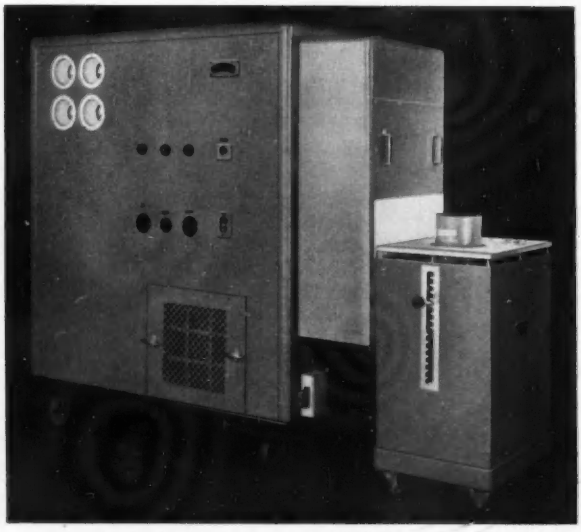


Fig. 78.—Induction furnace in use with 5 kW high frequency heating set.

sections of the stoving oven are switched on first, then the other sections in turn progressively towards the ends, and finally the conveyor. In this way articles inside the stoving plant are given a boost to compensate for the inadequate stoving they would otherwise receive owing to the cooling taking place during the shut-down period.

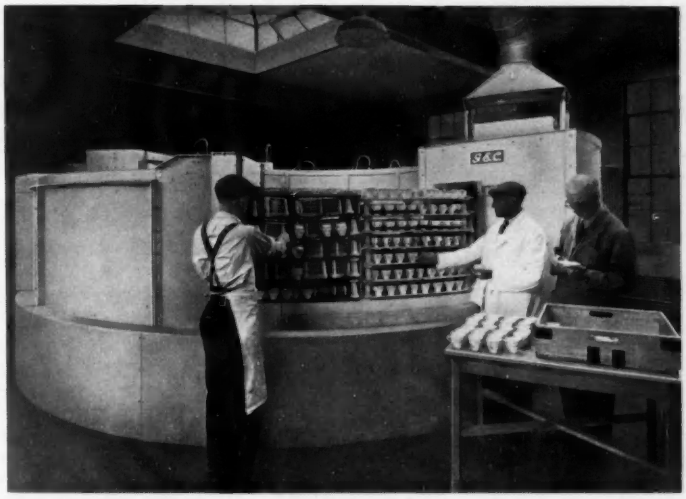


Fig. 79.—55 kW rotary hearth decorating kiln to handle 3,000 dozens of ware per week.

AGRICULTURAL EQUIPMENT.

Increased milk production is a matter of national importance and the maintenance of a high standard of purity is essential. An extensive range of equipment for this purpose has been produced in the past and new items have been added recently.

A thermal storage sterilising chest (fig. 82) has recently been introduced to supplement the well-established range of directly heated chests for use on dairy farms. One of the principal advantages of the storage type is the low electrical loading of only 1 kW. This allows its use on supply mains which would be overloaded by directly heated models. Another point of importance under present circumstances is that the operation of the chest is unaffected by load shedding. Heat is stored in a well-insulated iron block incorporating heaters specially designed to withstand the particular operating conditions and fitted with terminals outside the hot zone.

A novel method of supplying feed water to the storage block steam generator is employed. A small tank mounted on the side of the cabinet

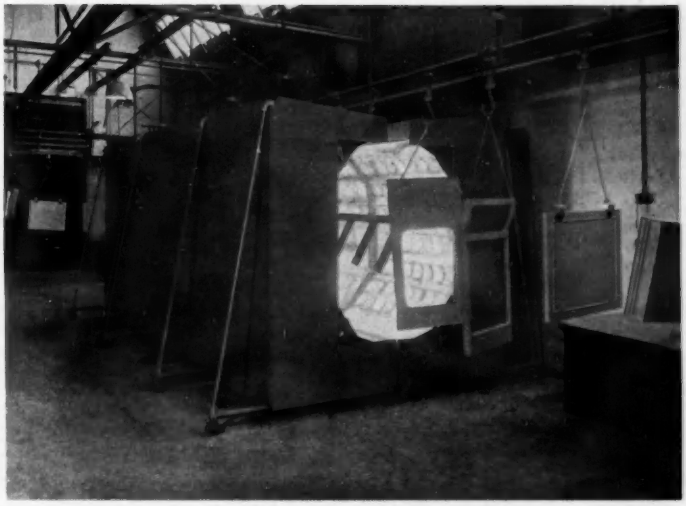


Fig. 80.—Internal reflector radiant heating plant for stoving paint on kitchen cabinets.

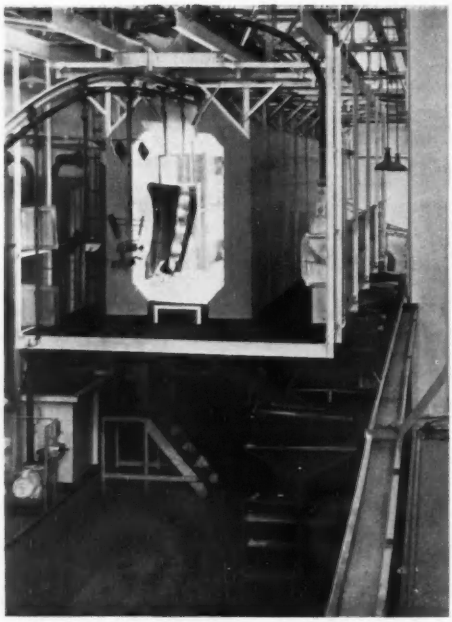


Fig. 81.—Part of a 480 kW radiant heating installation of reflector lamp plants for drying and stoving paint on aluminium body components of cars.

holds a predetermined quantity of water which is fed to the block at a controlled rate. The use of the correct amount of water for each operation is thereby ensured and the maximum operating efficiency is obtained, while waste of stored heat which may be required for subsequent operations is avoided. The stored heat is available for rapid generation of steam and with a normal load of dairy utensils the sterilising temperature of 210 degs. F. is attained inside the cabinet in under ten minutes.

The older chests have given excellent service on farms in every part of the country for many years and have responded well to all the demands made upon them. However, the water available for the chests varies greatly in its degree of hardness and difficulty has been experienced when the temporary hardness is high. To counteract the risk of furring in such cases a new patented arrangement has been introduced which ensures that the ball valve head temperature will not exceed 100 degs. F.—a temperature at which formation of fur is negligible (fig. 83). The construction of the water feed tank, however, is such that the ball valve is readily accessible.

With the new arrangement, a ball valve tank sealed to the atmosphere is used, and the pressure equalising pipe between the boiler and the feed tank is arranged to contain an appreciable volume of air and to have only a small outlet orifice inside the feed tank. When the pressure in the boiler rises slightly as steam is generated, the air in the connecting pipe and at the top of the ball valve tank is compressed, but there remains an effective air seal between the two tanks so that steam circulation and heating of the feed water cannot occur.

Both the storage block and the directly heated sterilising chests are fitted with an improved form of steam entry into the top of the cabinet which shortens the steaming time and increases the operating efficiency by nearly 30 per cent.

DOMESTIC APPLIANCES.

Past experience has shown the value of circulator type domestic water heaters which enable small quantities of hot water to be obtained very soon after switching on. An improved design incorporating withdrawable cartridge elements[1] and a thermostat is shown in fig. 84. The elements are mounted at the bottom of the circulator tube, so that rapid circulation is induced, and can be withdrawn without draining the container. The thermostat is long enough to ensure control of

[1] *G.E.C. Journal*, Vol. XV, No. 1, p. 41, February, 1948.

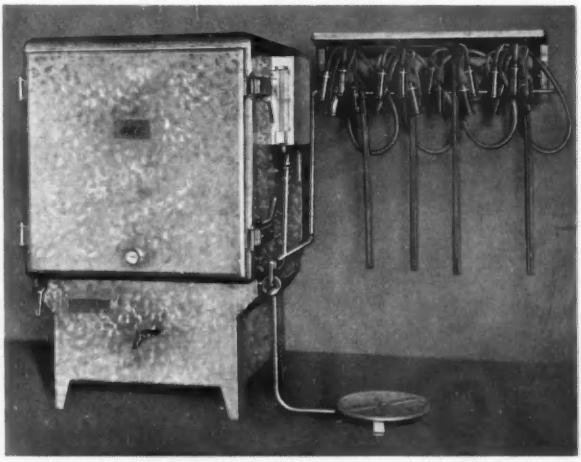


Fig. 82.—Storage block type electric sterilising chest with cluster rack and churn stool.

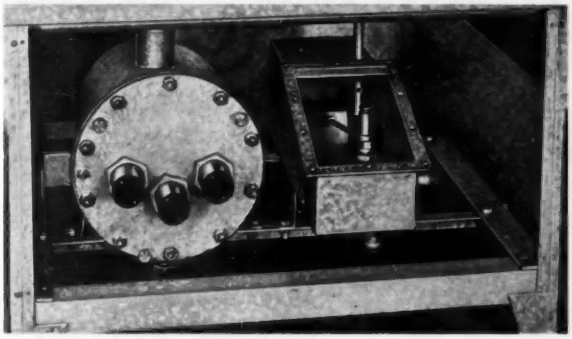


Fig. 83.—Steam generator and water feed tank of directly heated sterilising chest.

water temperature throughout the container and as its sheath is outside the circulating tube it effectively controls the main bulk of water. In common with other designs this circulator is suitable for use only in soft and moderately soft water districts.

The existing hair drier was designed some years ago, and while entirely satisfactory in operation left something to be desired in the matter of appearance. This has been remedied in the new model which is designed on attractive modern lines, as can be seen in fig. 85. It is somewhat smaller than the original model and possesses several other new features which experience has shown to be desirable.

The air inlet is directly above the switch, and well away from the outlet, so that there is no danger of the hair being drawn into the fan. As an extra precaution, an efficient guard is provided over the inlet aperture. The flow of air is axial throughout, passing over the motor and heater on its way to the outlet. The heating element is wound on a ceramic former and is protected from damage by a vitreous enamelled steel grid over the outlet. The casing is made up of three mouldings executed in cream coloured plastic. Every precaution has been taken to ensure safety; no screws are exposed on the outside of the hair drier which is completely insulated and can be used anywhere. When mounted on the stand seen in the illustration, the drier can conveniently be stood on a table.

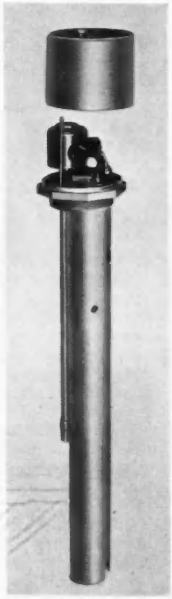


Fig. 84.—Internal circulator for water heating, with withdrawable cartridge type elements and thermostat.

Fig. 85.—New design of hair drier.

TECHNICAL LITERATURE

A DIGEST OF RECENT BOOKS, ARTICLES AND PAPERS, BY MEMBERS OF THE G.E.C. AND ITS ASSOCIATED COMPANIES.

FRACTIONAL HORSEPOWER ELECTRIC MOTORS.

A guide to Types and Applications.

By E. K. Bottle (Fractional Horsepower Motor Department, Witton Engineering Works).

Charles Griffin & Company Ltd., London, W.C.2. 205 pp., 109 diagrams, price 15/-.

This book is specifically addressed to the inventor and designer of motor-driven appliances and contains information to facilitate the choice of the best machine for the job. The whole field of application of fractional horsepower motors including telemotor systems and motor control gear is surveyed. There is much of interest for students and for all concerned with the sale, installation and maintenance of motor-driven appliances.

THE INSIDE OF ELECTRICAL MACHINES.

By R. H. Robinson (Insulation Engineer, Witton Engineering Works).

Ernest Benn Ltd. 252 pp., 133 illustrations, price 18/-.

A concise and comprehensive treatise on the manufacture and testing of every type of electrical insulation for use in machines of all sizes from vacuum cleaners to turbo-alternators. Many useful tables and curves are given. The later chapters deal fully with the applications of insulation to machine windings.

MAGNETIC MATERIALS.

By F. Brailsford (Metropolitan Vickers Electrical Co.)
D. A Oliver, D. Hadfield (William Jessop & Sons Ltd.), and
G. R. Polgreen (Salford Electrical Instruments Ltd.).

Jour. I.E.E., Vol. 95, Pt. I, No. 96, December, 1948.

The development of the theory of ferromagnetism over the past two or three decades is briefly reviewed and some of the more outstanding relevant laboratory investigations are discussed, including work on the effect of impurities, the magnetic properties of single crystals, on hydrogen annealing and on heat treatment in a magnetic field. The development and properties of the cold-rolled silicon steels for transformers are then reviewed, as well as advances in the hot-rolled steels. Cobalt iron alloys with magnetic saturation values higher than for iron are discussed. Finally, the development of the nickel-iron alloys is traced, concluding with the most recent advance in this field.

OPERATING CHARACTERISTICS OF MULTIPLE UNIT TRAINS.

By J. E. Bowler (G.E.C. Traction Department).

The Railway Gazette, Vol. 90, No. 20, 20th May, 1949.

The performance of a post-war 1,500 volt suburban multiple unit train is compared with that of a typical steam hauled suburban train over portions of the Liverpool Street-Shenfield route. Higher tractive efforts and better adhesion provide high accelerations with saving in time especially over short runs. Other advantages are higher power-to-weight ratios and uniformity of performance with automatic acceleration.

FACTORS INFLUENCING THE PERFORMANCE OF DIESEL-ELECTRIC TRACTION EQUIPMENT.

By J. E. Bowler (G.E.C. Traction Department).

Diesel Railway Traction No. 205, June, 1949.

The requirements commonly laid down in purchasers' specifications for diesel-electric locomotives and railcars are discussed. Methods of meeting such requirements by variations in the design of engine, generator and motors are considered with reference to typical individual performance characteristics of such machines.

V.H.F. VALVES AND CIRCUITS (390).*

By M. R. Gavin (Research Staff of the M.O. Valve Co. Ltd., at the G.E.C. Research Laboratories).

Wireless Engineer, Vol. XXV, p. 315, October, 1948.

This article discusses some of the aspects of negative-grid valves and their circuits, which have not previously been published, and indicates certain possible lines of future development.

GRID CURRENT WITH RC COUPLING (399).*

By H. T. Ramsey (Research Staff of the M.O. Valve Co. Ltd., at the G.E.C. Research Laboratories).

Wireless Engineer, Vol. XXVI, p. 113, April, 1949.

A common feature of multi-vibrator circuits is that the valves forming them are driven into grid current during some part of each cycle. These currents produce, across the coupling capacitors, potentials that play a significant part in the operation and determine the minimum value that the coupling capacitance may be given. The following discussion attempts to analyse these effects in the general case of a valve driven into grid current by a square-wave through capacitance coupling.

CHARACTERISTICS OF THE CRATER OF THE HIGH INTENSITY CARBON ARC (400).*

By V. J. Francis, F. S. Hawkins and A. H. Willoughby (Research Laboratories).

Phil. Mag. Ser. 7, Vol. XL, p. 546, May, 1949.

The paper describes experimental investigations on the burning characteristics of a range of high intensity positive carbons. The properties studied were the rate of burn of the positive carbon, with respect to the effects of external oxidation and internal evaporation; the crater diameter and depth; the arc voltage; and the axial candles. An attempt is made at a theory of operation of the high intensity arc, which explains the mechanism of the arc in relation to the crater formation and other associated phenomena. The experimental results support reasonably well the assumptions on which this theory is based.

THERMIONIC EMISSION FROM OXIDE COATED CATHODES (402).*

By D. A. Wright (Research Staff of the M.O. Valve Co. Ltd., at the G.E.C. Research Laboratories).

Proc. Phys. Soc. B, Vol. LXII, p. 188, 1949.

It is shown experimentally that with Ba/Sr oxide cathodes, the saturated emission depends on the core material in use, and there is some correlation between total coating resistance and saturated pulsed emission.

It is shown that the application of semi-conductor theory can give a consistent account of coating conductivity and emission, provided the concentration of barium in stoichiometric excess is about 3×10^{17} atoms/cm^3.

With thoria there is little difference thermionically when studied as a coating on tantalum or on tungsten, or as a ceramic tube. Experiment and theory indicate that thoria is an excess semiconductor containing a stoichiometric excess of about 10^{18} atoms/cm^3 of thorium.

***A limited number of reprints is available of those papers marked with an asterisk. Copies may be obtained on application to the Editor, G.E.C. Journal, Magnet House, Kingsway, W.C.2.**